U.S. ARMY CORPS
OF ENGINEERS

MAJOR REHABILITATION REPORT:
MAIN REPORT and ENVIRONMENTAL ASSESSMENT

BOLIVAR DAM
SANDY CREEK OF THE TUSCARAWAS RIVER, OHIO

PREPARED BY: USACE, HUNTINGTON DISTRICT

DRAFT REPORT FOR PUBLIC REVIEW – JULY 2008

DRAFT
FINDING OF NO SIGNIFICANT IMPACT

Major Rehabilitation Project,
Bolivar Dam, Muskingum River Basin, Ohio

1. I have conducted an environmental assessment in the overall public interest concerning implementation of the Major Rehabilitation of the Bolivar Dam. This purpose of this project is to address problematic seepage at Bolivar Dam. Action is needed because the excessive uncontrolled seepage is negatively affecting the structural stability of the dam resulting in increased risks to the downstream public. Due to the history of excessive seepage through and under the dam and through the left abutment during events with frequent return periods, it was ranked by the U.S. Army Corps of Engineers Screening for Portfolio Risk Assessment (SPRA) process as a Dam Safety Action Class II – Urgent (unsafe or potentially unsafe) project. Rehabilitation is needed to correct these seepage problems and to minimize the potential for catastrophic failure of the dam during such events.

2. Several alternatives were considered to address the problematic seepage at Bolivar Dam many of which were screened in the formulation process. Alternatives retained for detailed consideration include, 1.) Partial Depth/Length Concrete Seepage Barrier (Main Embankment) 2.) Seepage Cutoff Wall (Left abutment) 3.) Combination (Main Embankment + Left Abutment) 4.) No Federal Action. The recommended alternative resulting from the formulation process is a combination of Left Abutment and Main Embankment seepage barrier.

3. Major construction features of the selected plan include a partial-depth and partial-length concrete seepage barrier on the upstream toe of the dam, a seepage barrier cutoff wall in the left abutment of the dam, augmentation of the existing downstream seepage blanket, rehabilitation of the operating machinery and gates, the maintenance and/or rehabilitation of the existing relief well system as necessary to maintain adequate efficiency, instrumentation-related improvements (for existing piezometers and relief wells), and the installation of additional instrumentation (piezometers, surface displacement monuments, and inclinometers) to provide adequate post-remediation monitoring capability.

4. The possible consequences of the project have been studied for biological, cultural and social effects. Another factor bearing on my assessment was the capability of the project to meet the public needs for which it was proposed. The following references that assessment:

a. <u>Biological Considerations.</u> The Huntington District has taken reasonable measures to assemble and present the known or foreseeable environmental impacts of the project in the environmental assessment. These impacts involve biological and human resources. No significant impacts to biological resources would occur as a result of the proposed action. All adverse effects of project implementation are insignificant or may be avoided through management techniques.

b. Social Well-Being Considerations. The proposed project will provide benefits to the downstream areas regardless of ethnic or socioeconomic status, and the project would not disproportionately affect low-incomes or minority populations. Moreover, the project would not create adverse human health or environmental effects. No significant economic or social well-being impacts are foreseen as a result of the proposed action.

c. Cultural Resource Considerations. There is a high probability that archaeological sites will be impacted by the proposed actions. The Corps has engaged in informal consultation with the State Historic Preservation Office (SHPO), pursuant to the regulations (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (NHPA). Detailed surveys, testing, evaluation, effect determination and mitigation planning will be performed prior to implementation of the major rehabilitation work. Coordination with the State Historic Preservation Office will be maintained throughout this process to ensure full compliance with Section 106 of the NHPA.

d. Coordination with Resources Agencies. Pursuant to the Fish and Wildlife Coordination Act (FWCA) of 1958, coordination with the U.S. Fish and Wildlife Service has been made. No significant effects on fish and wildlife would occur as a result of the proposed action. To avoid impact to Federally Listed Indiana Bat, clearing activities would be limited to winter months (September 30 to April 1) while the Indiana bat is in hibernation. In accordance with the Endangered Species Act, as amended, the selected plan would not impact listed species.

e. Other Pertinent Compliance. The proposed action is also in compliance with the National Historic Preservation Act, (Section 10632 CFR 300), Executive Order (EO) 11988 (Floodplain Management) and EO 11990 (Protection of Wetlands).

f. Other Public Interest Considerations. Public involvement activities include meetings with local officials, resource agencies and public meetings. There has been no significant opposition to the proposed action by State or local Governments, or organized environmental groups. The Bolivar Dam Major Rehabilitation Report and EA will be made available to environmental resource agencies, both federal and state, as well as the general public and other interested agencies, groups and individuals for a 30-day review period. Comments received during the public review period have been included in the Final Environmental Assessment. There are no unresolved issues regarding the implementation of the project.

g. Section 176(c) Clean Air Act. The proposed action has been analyzed for conformity applicability pursuant to regulations implementing Section 176(c) of the Clean Air

DRAFT
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Major Rehabilitation Project,
Bolivar Dam, Muskingum River Basin, Ohio

Act. The proposed action is exempted by 40 CFR Part 93.153 from making a conformity determination, since estimated emissions from construction equipment will not exceed *deminimis* levels or direct emissions of a criteria pollutant or its precursors. Therefore, no significant impacts to air quality would be expected from the proposed action. Any later indirect emissions are generally not within the Districts' continuing program responsibility and generally cannot be practicably controlled by the District.

5. I find the Major Rehabilitation Project, Bolivar Dam, has been planned in accordance with current authorization as described in the Environmental Assessment. The project is consistent with National policy, statutes, and administrative directives. This determination is based on thorough analysis and evaluation of the project and alternative courses of action. In conclusion, I find the proposed Project will have no significant adverse effect on the quality of the human and/or natural environment.

DATE

DANA HURST
Colonel, Corps of Engineers
Commanding

BOLIVAR DAM
MUSKINGUM RIVER BASIN, OHIO

DAM SAFETY ASSURANCE PROGRAM
MAJOR REHABILITATION REPORT AND ENVIRONMENTAL ASSESSMENT

EXECUTIVE SUMMARY

General

The Huntington District has completed a Draft Major Rehabilitation Report and Environmental Assessment for the Bolivar Dam, Muskingum River Basin, Ohio. The report was prepared in accordance with Corps Major Rehabilitation guidance in EP 1130-2-500 dated 27 December 1996. Draft ER 1110-2-1156 *Safety of Dams-Policy and Procedure* dated 29 April 2003 was also consulted for guidance. Pursuant to the National Environmental Policy Act and Council of Environmental Quality implementing regulations (43 CFR 55900, Nov. 28, 1978, Section 1500.2(c)), this document integrates the requirements of NEPA with other USACE planning requirements.

Bolivar Dam is located in Stark and Tuscarawas Counties, Ohio on Sandy Creek of the Tuscarawas River, a tributary of the Muskingum River, 183.4 miles upstream of the confluence with the Ohio River. The project is located about one mile upstream of the city of Bolivar and 13 miles upstream of the city of Dover, Ohio. Bolivar Dam was completed in September 1938, and is a two-zoned, rolled earthfill embankment with an impervious core and pervious upstream and downstream shells. The embankment is keyed into bedrock where outcrops are present at the left (South) abutment. Bedrock is composed of Pennsylvanian shales, indurated clays, limestones, and thin beds of sandstone and coal. The total crest length is 6,400 feet with approximately 1,400 feet at a height of 87 feet and 5,000 feet of a lower level dike from 20 feet to 50 feet high. The foundation of the dam is glacial outwash material and the depth to bedrock is up to 230 feet below the crest of the dam. The top width of the dam is 25 feet and has been raised from elevation 982 feet to elevation 985.5 feet by construction of a 3.5-foot high parapet wall along the upstream face of the dam. The dam was raised and the spillway widened to address the hydrologic deficiency. This work was completed in 1989.

Purpose and Need for Agency Action

This purpose of this project is to address problematic seepage at Bolivar Dam. Action is needed because the excessive uncontrolled seepage is negatively affecting the structural stability of the dam resulting in increased risks to the downstream public. Due to the history of excessive seepage through and under the dam and through the left abutment during events with frequent return periods, it was ranked by the U.S. Army Corps of Engineers Screening for Portfolio Risk Assessment (SPRA) process as a Dam Safety Action Class II – Urgent (unsafe or potentially unsafe) project. Rehabilitation is needed to correct these seepage problems and to minimize the potential for catastrophic failure of the dam during such events.

This report documents the evaluations conducted to support a decision to correct the serious seepage problems at Bolivar Dam under the USACE Major Rehabilitation Program.

Alternatives Evaluation

The plan formulation was conducted in two phases, initial screening and selection of recommended alternative.

During initial phases of project formulation, several alternatives were considered to address the stated purpose and need. As indicated in the engineering studies, two separable component features of the Bolivar Dam were determined to be in need of rehabilitation. These components are the main embankment and left abutment. As separable components they have been justified independently of each other. Therefore, alternatives to address planning objectives were developed for each component. These alternatives were evaluated based on their ability to meet project objectives considering engineering, economic and environmental feasibility. From this initial screening, four alternatives were retained for detailed consideration. These alternatives are listed below:

1. Partial Depth/Length Concrete Seepage Barrier (Main Embankment)
2. Seepage Cutoff Wall (Left abutment)
3. Combination (Main Embankment + Left Abutment)
4. No Federal Action or Base condition

For the final screening, the alternatives which were not eliminated were analyzed both independently and in combination to determine the most economic investment. As the environmental effects of final alternatives are considered minor and insignificant, all alternatives were considered nearly equal in terms of environmental acceptability. As such economic considerations were used as the main consideration in the final screening. The table below summarizes the results of the economic analysis of the final rehabilitation alternatives.

Summary of Economic Considerations – FY08 Price Level (baseline level)				
Individual Component or Combination	Average Annual Benefits	Average Annual Costs	Net Benefits	BCR
Main Embankment (Partial Length/Depth Cutoff)	$12,382,000	$7,067,000	$5,315,000	1.8
Left Abutment (Cutoff + Grouting)	$373,000	$224,000	$150,000	1.7
Main Embankment + Left Abutment	**$12,699,000**	**$7,218,000**	**$5,481,000**	**1.8**

The combination of Main Embankment Partial Length/Depth Cutoff and Left Abutment Cutoff Wall is considered the recommended plan as it maximizes net project benefits. This alternative is also the National Economic Development (NED) plan. The average annual benefits for the recommended plan are approximately $12.7 million. The average annual costs are approximately $7.2 million resulting in a benefit to cost ratio of 1.8.

Recommended plan

Major construction features of the recommended plan include a partial-depth and partial-length concrete seepage barrier on the upstream toe of the dam, a seepage barrier cutoff wall in the left abutment of the dam, augmentation of the existing downstream seepage blanket, rehabilitation of the operating machinery and gates, the maintenance and/or rehabilitation of the existing relief well system as necessary to maintain adequate efficiency, instrumentation-related improvements (for existing piezometers and relief wells), and the installation of additional instrumentation (piezometers, surface displacement monuments, and inclinometers) to provide adequate post-remediation monitoring capability.

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1.0 PROJECT BACKGROUND

1.1 Authority

Bolivar Dam is one of a system of reservoir projects in the Muskingum River Basin (Figure 1) in Ohio, authorized and constructed in cooperation with the Muskingum Watershed Conservancy District (MWCD). This Conservancy District, a public corporation, was created on 3 June 1933, for the purpose of developing a plan for flood control, water conservation, and water use in the Muskingum River Basin.

A general plan was prepared, and an application for approval of the project with a request for financial cooperation was filed with the Administration of Public Works in August 1933. The Public Works Administration approved the project in December 1933 and allocated funds to the U. S. Army Corps of Engineers (USACE) to aid in financing the construction of the project. USACE initiated investigations following execution of a contract between the United States of America and the Muskingum Watershed Conservancy District on 29 March 1934. The official plan was prepared by the USACE and accepted by MWCD on 19 November 1934.

Bolivar Dam was completed in 1938. The Federal Government, through the Corps of Engineers, was responsible for the projects construction and relocation of public utilities. MWCD cost shared the project and procured lands, easements, and right-of-way needed for the project and was subsequently reimbursed for these expenditures by the Federal Government.

The Flood Control Act, approved 11 August 1939, contained a provision that the dams and reservoirs be included in the Comprehensive Flood Control Plan for the Ohio River Basin, and Operation and maintenance of the reservoir system have been the responsibility of the Corps of Engineers since that date. The project is operated in cooperation with MWCD to provide flood control, recreation, and fish and wildlife enhancement.

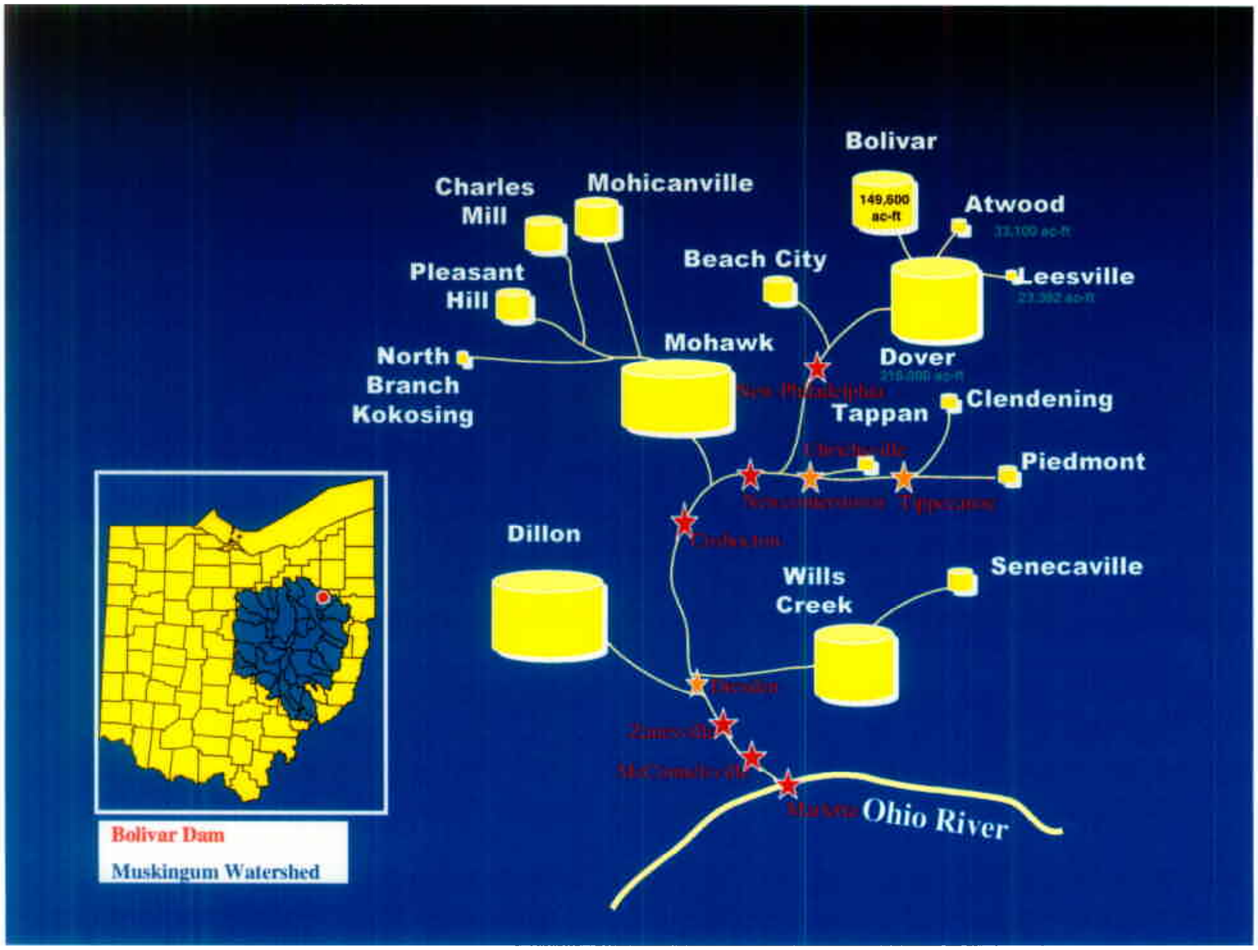

Figure 1. Locations of the Muskingum River Basin and Bolivar Dam in Ohio (left), and USACE-operated projects within the basin (right).

1.2 Purpose and Need

This purpose of this project is to address problematic seepage at Bolivar Dam. Action is needed because the excessive uncontrolled seepage is negatively affecting the structural stability of the dam increasing risks to the downstream public. Due to the history of excessive seepage through and under the dam and through the left abutment during events with frequent return periods, it was ranked by the U.S. Army Corps of Engineers Screening for Portfolio Risk Assessment (SPRA) process as a Dam Safety Action Class II – Urgent (unsafe or potentially unsafe) project. Rehabilitation is needed to correct these seepage problems and to minimize the potential for catastrophic failure of the dam during these and greater events. This report documents the evaluations conducted to support a decision to correct the serious seepage problems at Bolivar Dam under the USACE Major Rehabilitation Program.

1.3 Definitions

Definitions are provided below to assist the lay reader in understanding technical terms used throughout this report.

Headcut Erosion – An erosion feature within a stream presenting as an abrupt vertical drop or "step"in the bed of a stream channel which migrates upstream.
Inclinometer - an instrument for measuring angles of slope (or tilt), elevation or inclination of an object with respect to vertical.
Piezometer - small diameter water well used to measure the hydraulic head of seepage through the dam embankment.
Piping - Piping is a subsurface form of erosion which involves the removal of subsurface soils in pipe-like erosional channels to an area in which it is free to exit.
Relief Well - A well that is used to relieve water pressure from an aquifer. These types of wells can be used to control underseepage in dams and wiers.
Stations - A point along a baseline typically delineated at 100 foot intervals, i.e., Station 26+00 would be 2600 feet from the beginning point.

1.4 Other NEPA Documents

Documentation of the "without project" conditions for this report assumes the completion of the proposed Interim Risk Reduction Measures (IRRMs) at the Bolivar Dam. USACE policy as prescribed in EC 1110-2-6064 (Interim Risk Reduction Measures for Dam Safety, 2007) dictates the district develop, prepare, and implement IRRMs to reduce the probability and consequences of catastrophic failure to the maximum extent reasonably practicable while long-term remedial measures are pursued. The proposed IRRMs for Bolivar include numerous maintenance and administrative actions at the dam site, the majority of which do not require evaluation and documentation under the National Environmental Policy Act (NEPA). Those IRRM measures that do require evaluation under NEPA will be addressed and documented in a separate environmental assessment.. The IRRMP Draft EA is to be released for public circulation in the summer of 2008. It is anticipated that all measures proposed for the Bolivar Dam will be completed by the end of the 2009 calendar year. Further discussion regarding IRRMs are included in Section 9.7 of this report and in the Draft IRRMP, which documents all measures proposed for the Bolivar Dam included in Appendix M.

2.0 PROJECT LOCATION AND DESCRIPTION

2.1 Location

Bolivar Dam is located in Stark and Tuscarawas Counties, Ohio on Sandy Creek of the Tuscarawas River, a tributary of the Muskingum River, 183.4 miles upstream of the confluence with the Ohio River. The project is located about one mile upstream of the city of Bolivar and 13 miles upstream of the city of Dover, Ohio (Figure2).

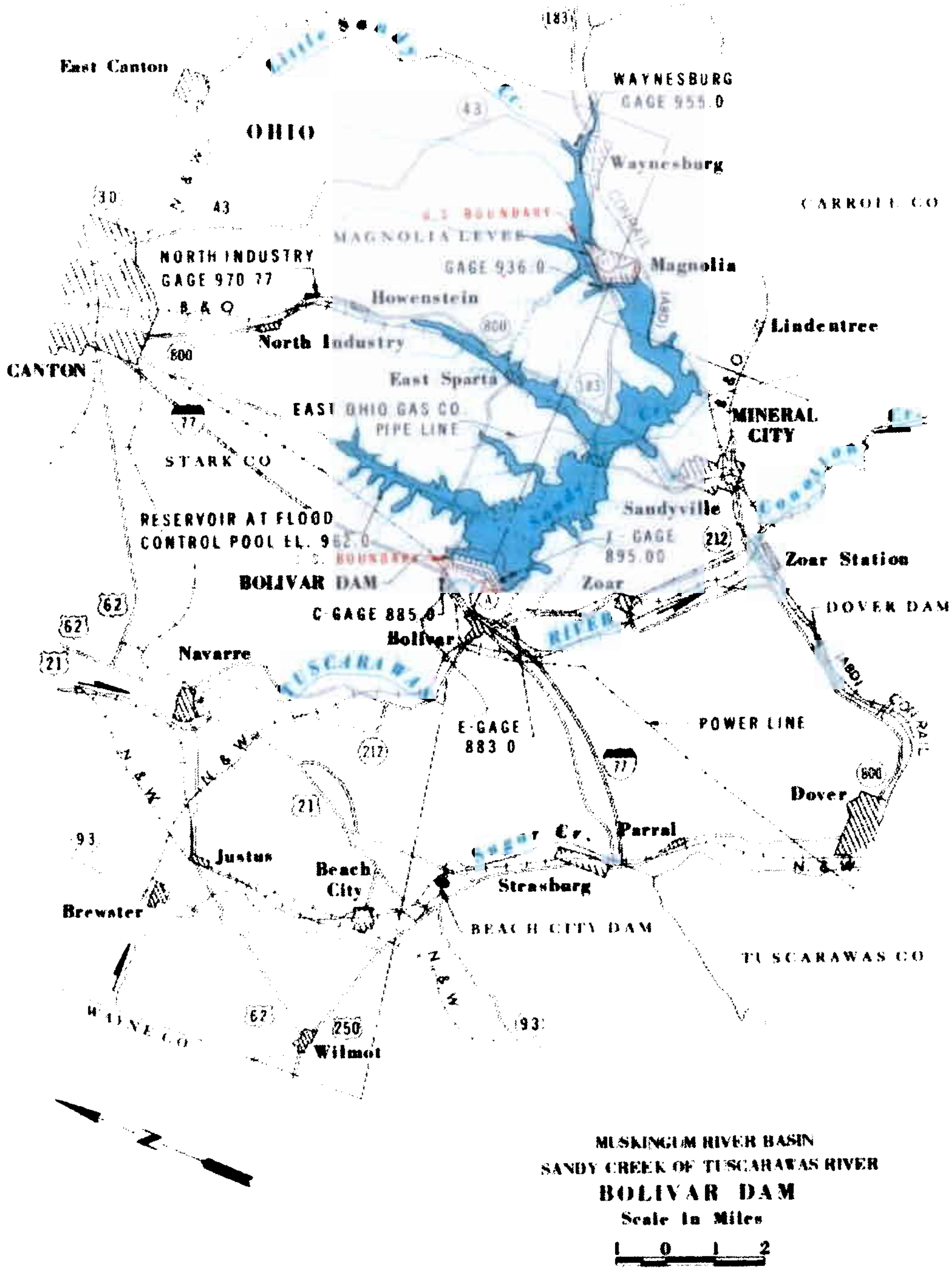

Figure 2. Location of Bolivar Dam.

2.2 Description

Bolivar Dam is a “dry dam” and does not retain a permanent pool during any season of the year. The outlet works normally pass the entire flow of Sandy Creek, except during periods of flood retention. The amount of time required for flood retention varies from year to year. However, based on historical records, water is usually impounded for about 10% of a typical year. Refer to Appendix J section 8 (c) Reservoir Routing Procedure for a more detailed description of how the project is operated during flood events. The project has an upstream drainage area of approximately 500 square miles, and 149,600 acre feet of storage at spillway crest.

2.2.1 Dam

Bolivar Dam (Figure 3) was completed in September 1938, and is a two-zoned, rolled earthfill embankment with an impervious core and pervious upstream and downstream shells. The embankment is keyed into bedrock where outcrops are present at the left (South) abutment. Bedrock is composed of Pennsylvanian shales, indurated clays, limestones, and thin beds of sandstone and coal. The total crest length is 6,400 feet with approximately 1,400 feet at a height of 87 feet and 5,000 feet of a lower level dike from 20 feet to 50 feet high. The foundation of the dam is glacial outwash material and the depth to bedrock is up to 230 feet below the crest of the dam. The top width of the dam is 25 feet and has been raised from elevation 982 feet to elevation 985.5 feet by construction of a 3.5-foot high parapet wall along the upstream face of the dam. The dam was raised and the spillway widened during implementation of a Dam Safety Assurance (DSA) program to address the hydrologic deficiency. This work was completed in 1989.

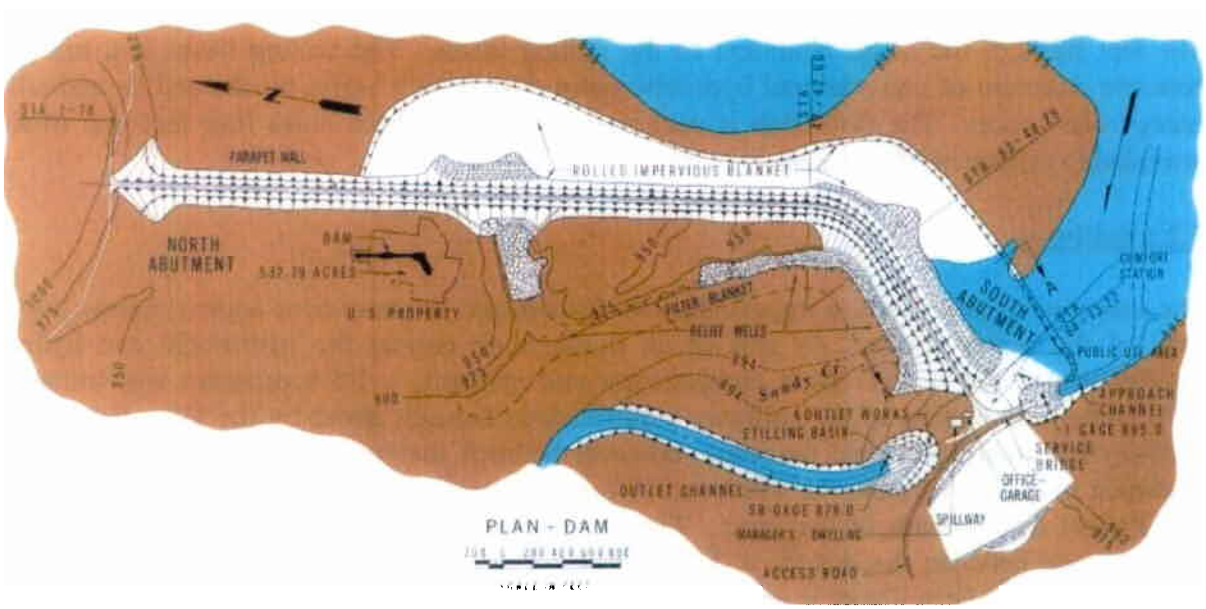

Figure 3. Plan view of the dam.

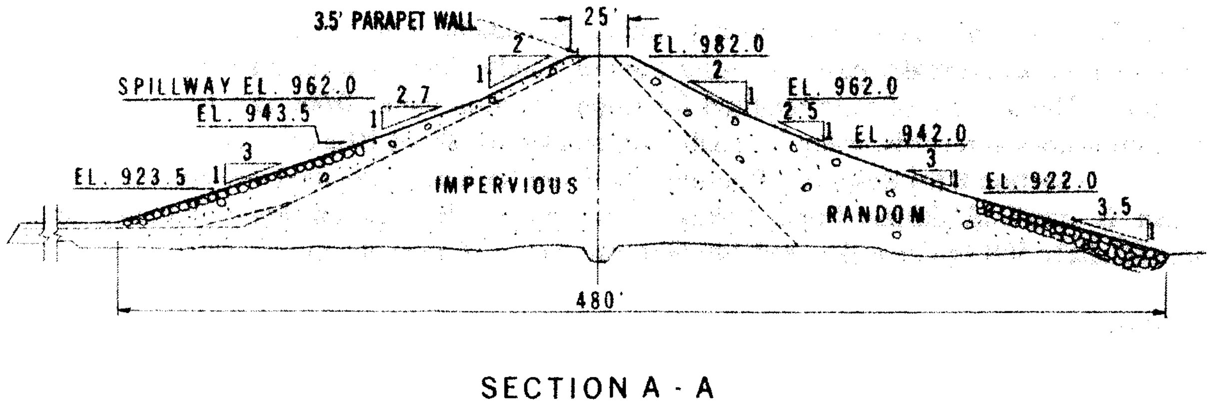

Figure 4. Cross section view of the dam. See location of Section A – A on Figure 3.

2.2.2 Outlet Works

The outlet works at the left abutment of the main embankment consists of twin concrete lined tunnels, an intake tower, walls, and stilling basin founded on rock. The intake structure consists of a reinforced concrete substructure and a brick superstructure. Six caterpillar gates, each 7.0 feet wide by 15.0 feet tall are contained in the intake structure and one emergency bulkhead lowered in place using the overhead crane. The invert of each gate opening is at elevation 895.0 feet. The outlet conduits consist of twin, 16-foot-diameter horseshoe-shaped, concrete-lined tunnels. The tunnels are connected to the intake structure through transition sections and extend 814 feet through the south abutment to the stilling basin. The stilling basin is a reinforced concrete structure of conventional hydraulic jump design with baffle blocks and an end sill for energy dissipation. The floor slab is anchored to rock and drain holes four feet into rock are provided to relieve uplift pressure.

2.2.3 Spillway

The emergency spillway is a trapezoidal cut through the left abutment approximately 300 feet west of the outlet works. As part of an initiative to correct the hydrologic and hydraulic deficiencies in the Bolivar Dam embankment and spillway, a DSA program was initiated in 1981. After completion of the spillway modifications brought about by the DSA Program, the spillway alignment remained the same; however bedrock material was removed from the right abutment in order to double the width to 540 feet, a concrete sill was placed at the crest, as well as 230 feet downstream of the crest. The downstream cutoff is 15 feet deep. A reinforced concrete pad between the cutoffs is 3 feet thick. The crest is located at elevation 962.0. The overall length of the spillway is approximately 1200 feet. The Spillway Design Flood (SDF) has a peak inflow of 196,000 cfs with a freeboard of 5.40 feet.

Although the modifications to the spillway were made to limit the amount of erosion that would occur during the spillway design flood, a quantitative analysis to determine the expected amount of erosion was not performed at that time. In order to ensure that a spillway failure would not occur due to headcut erosion, a spillway erodibility analysis was performed as part of this MRR using SITES software developed by the Natural Resources and Conservation Service. The results of this analysis are provided in Appendix I.

2.2.4 Instrumentation

Current instrumentation for monitoring the performance of the embankment and foundation of Bolivar Dam consists of twenty-seven surface displacement monuments (SDMs), sixty-one open tube piezometers, and thirty-five relief wells. Surface displacement monuments were originally installed along ranges at stations 26+00, 40+00, 55+00, and 60+00, and a replacement system of monuments was installed in 1987. A list of current piezometers being monitored at the dam is contained in Appendix H, Plates I-7 to I-9.

2.2.5 Seepage Blanket, Relief Wells and Upstream Stability Berm

Construction of a downstream seepage blanket, toe drain, and thirty-five relief wells were completed in 1982. The downstream seepage blanket (bank run sand material) extends 200 feet downstream of either the toe of the terrace or the toe of the dam (Figure 5) from station 25+00 to station 60+00, and is generally about six feet thick. The toe drain was installed just downstream of the rock toe and consists of a 24-inch diameter perforated, concrete pipe that is encapsulated with gravel and wrapped with a geotextile. The toe drain was then covered with seepage blanket material.

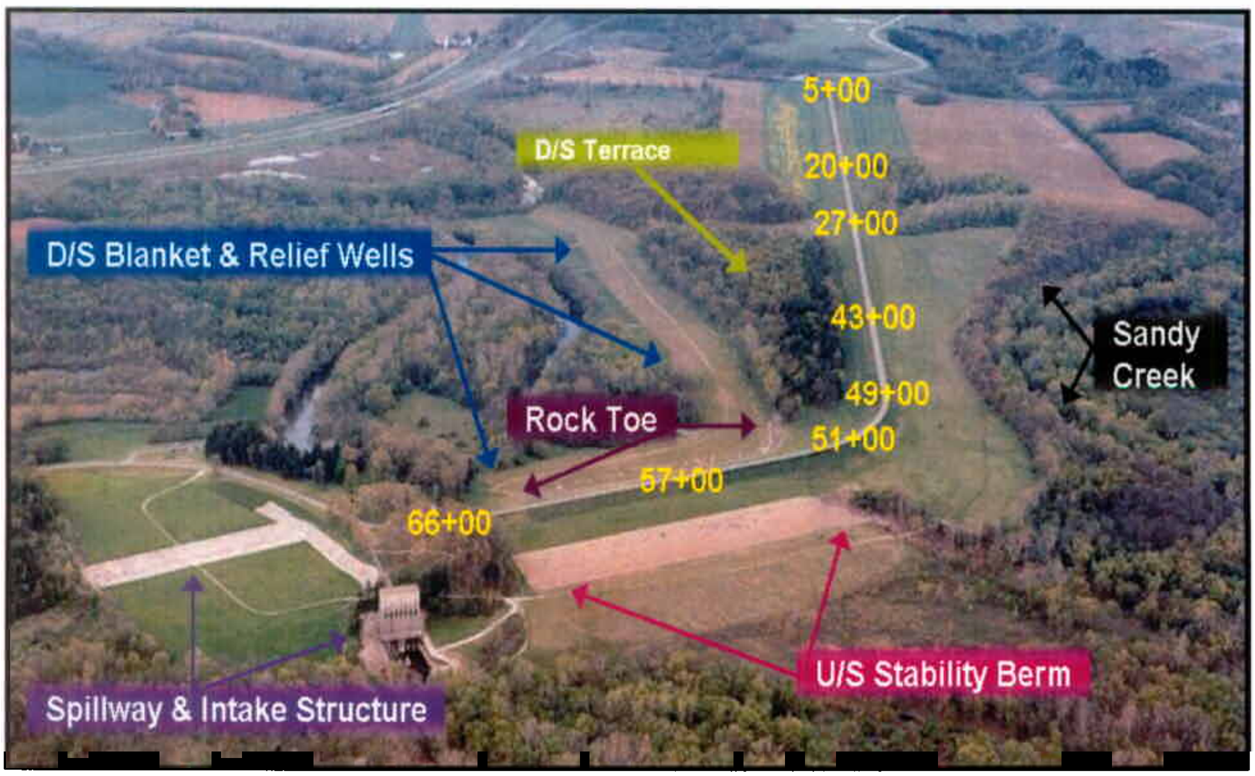

Figure 5. Northward aerial view showing features at Bolivar Dam.

The 35 relief wells (named W-2 through W-35, and W-23A) are also located between stations 25+00 and 60+00. The relief wells are located just downstream of the embankment or terrace toe, are typically 85 feet deep with a bottom elevation for the screened interval of 824 feet, and are typically spaced at 100 feet on center.

The construction of an upstream stability berm was completed in 1989 consisting of random, rock fill material placed to elevation 962 along the main embankment from station 52+00 to 65+00. The upstream stability berm has a 15 feet wide bench at elevation 962 with an upstream slope of 1 vertical on 4.5 horizontal, and is underlain by a 3 foot thick pervious blanket drain which is sloped to drain upstream. Construction drawings and more detailed information on these features is contained in Appendix H of this report.

3.0 PROBLEM IDENTIFICATION

3.1 Problem Description

3.1.1 Downstream Seepage

Bolivar Dam has a history of excessive uncontrolled downstream seepage (Figure 6) and the potential of through-seepage, underseepage, and slope instability at pools lower than spillway elevation. The Sandy Creek valley is a broad, deeply filled pre-glacial valley consisting of sorted glacial outwash materials with possible lenses of open work gravels. The glacial deposits, upon which the dam is founded are composed of pervious, fine to coarse gravelly sands, generally about 150 feet thick. Based on a review of the subsurface and instrumentation data, unsatisfactory performance of similar projects across the USACE inventory, and based on observed performance during the pool of record in 2005, it is believed that several areas of the embankment and/or foundation would become unstable due to piping at some pool less than the spillway crest level. This instability would threaten the integrity of the dam and could lead to a complete dam failure.

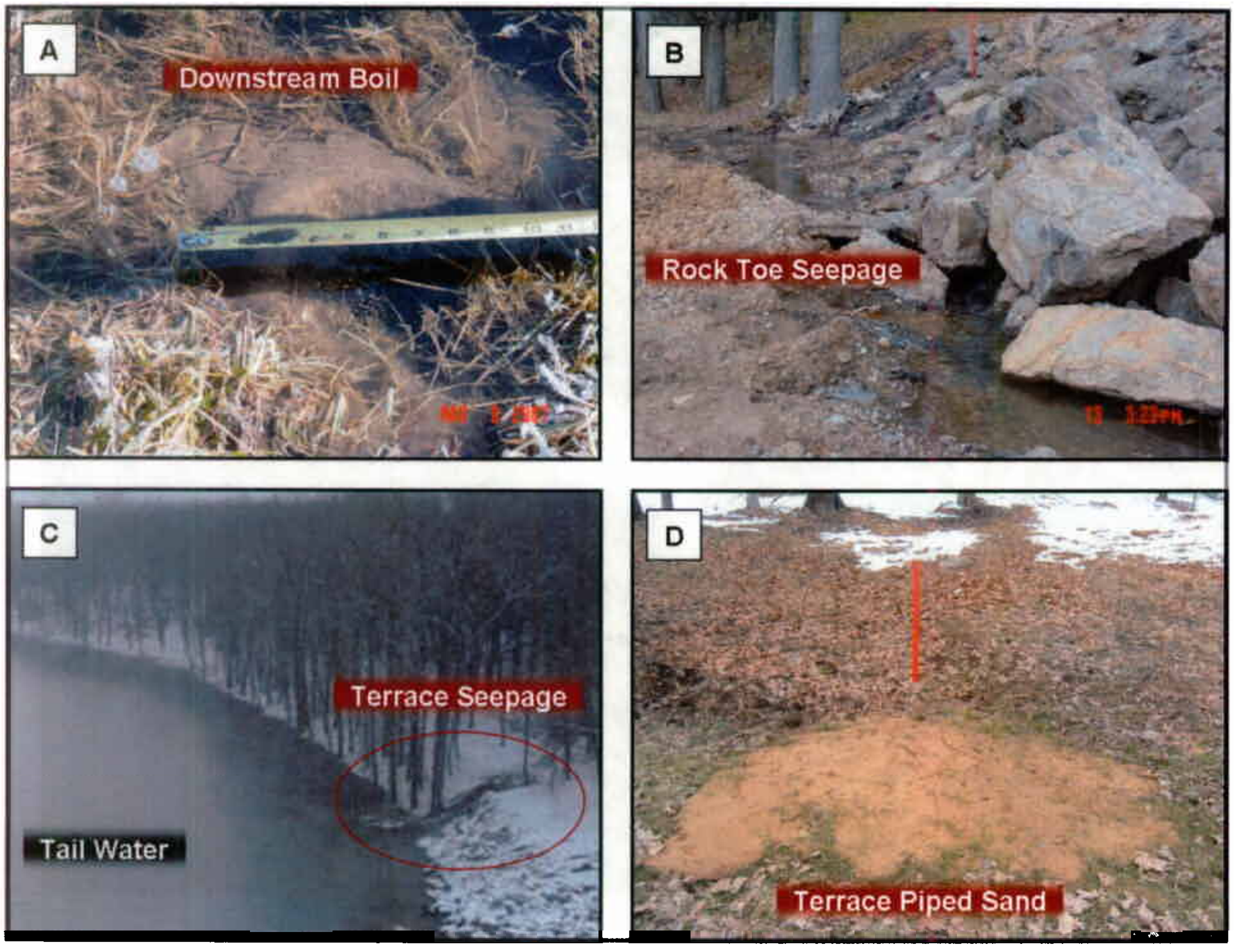

Figure 6. Photographs of seepage conditions. Near station 57+00, downstream area seeps and boils have been observed during events with <1-year return periods (A). Seepage at and above the rock toe has begun during events with a 3-year return period (B). During the record pool (94-year return period), excessive uncontrolled seepage exited the lower embankment and terrace slopes from stations 49+00 to 51+00 (C). Between stations 36+00 and 43+00, evidence of sand having been moved out of terrace deposits was apparent at the natural terrace slope toe during and after the record pool event (D).

3.1.2 Left Abutment Seepage

The left abutment was grouted during construction of the dam in 1937; however, significant seepage quantities (Figure 7) have historically begun exiting bedrock discontinuities at the cut slope of the outlet works at a pool elevation of 940 feet (10-year return period). The extent of the seepage path through the abutment bedrock cannot be verified; therefore, the future integrity of the abutment/embankment contact is in question. Rock seepage-related concerns at station 66+00 were addressed in this report through an expert elicitation process as part of Bolivar Dam's major rehabilitation study. See Appendix for the details of this study.

Figure 7. Left abutment seepage during January 2005 record pool.

3.1.3 Piezometers and Relief Wells

Shortcomings exist in the instrumentation for monitoring Bolivar Dam resulting from the downstream area being submerged beneath tail water during low-frequency events (Figure 8B). When the pool elevation is equal to or greater than 949 feet piezometric data have not been acquired, and may not be obtainable in the future at all downstream locations. Artesian flow above riser tops (not currently fitted with pressure gauges or other automated devices) has previously occurred during low-frequency events as well, and this has prevented data from being acquired throughout the events' duration. Relief well flow data cannot be acquired for this reason as well during low-frequency events. A second shortcoming of the relief wells is the likely potential for well performance to decline over time, coupled with the current lack of an implemented inspection, monitoring, and maintenance program. In general, wells suffer a loss in efficiency with time, for a variety of reasons such as clogging of screens and adjacent materials by fine particle infiltration, bacterial growth, and/or chemical incrustation.

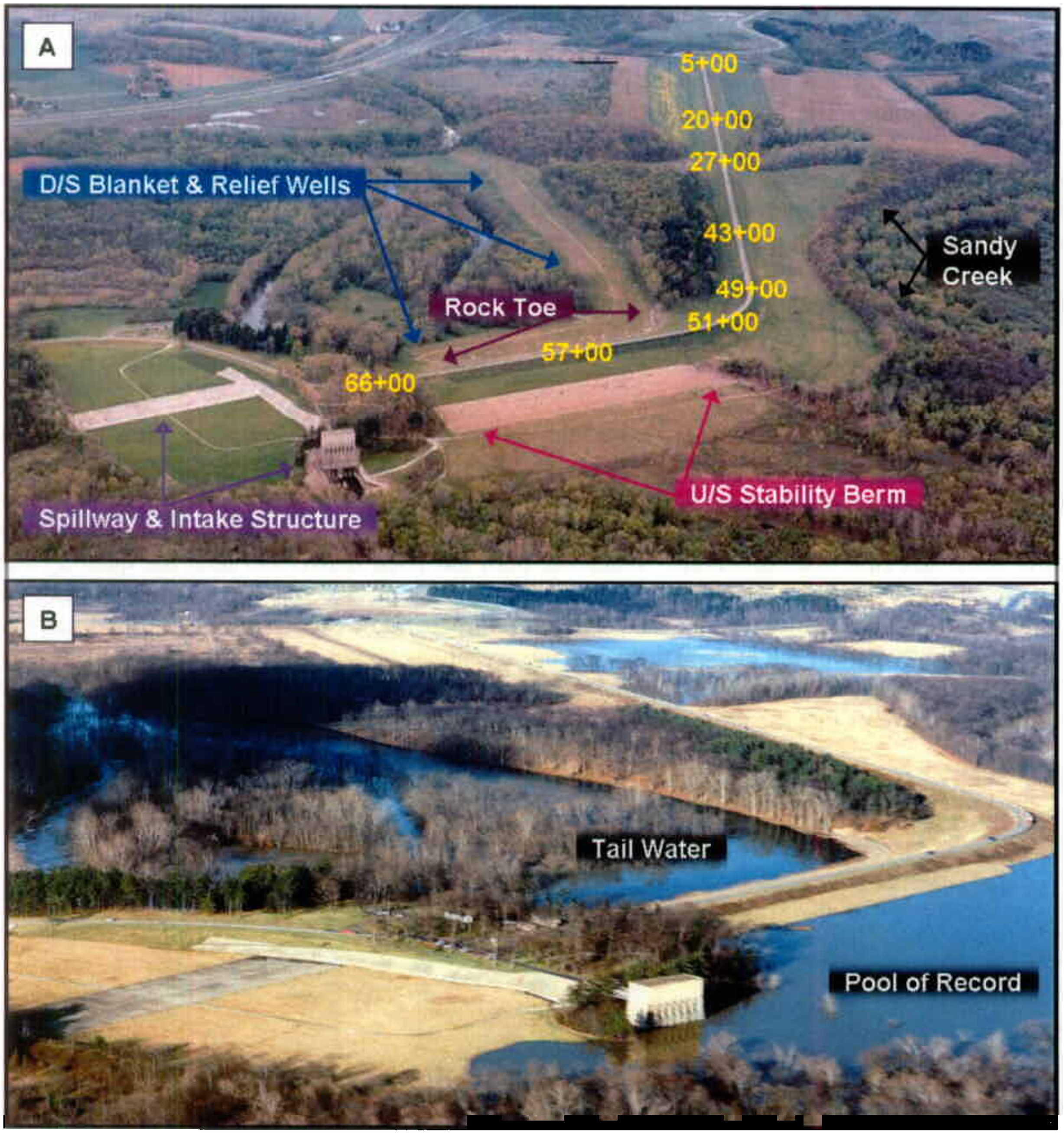

Figure 8. Northward aerial view of Bolivar Dam during normal operation with no pool retained (A). Aerial view towards the northeast during the January 2005 record pool; pool = 952 ft, tail water = 906 ft (B).

3.1.4 Operating Equipment and Gates

The gate operating equipment for all six gates is the original as constructed machinery which is 71 years old with the exception of some electrical upgrades which is estimated to have been performed about 1970. The emergency bulkhead is lowered into place using the overhead crane located in the intake structure. As the age of the equipment increases, the reliability of the equipment decreases thereby increasing the probability of unsatisfactory performance. The consequences of a machinery failure with the gates in the closed position would result in the project losing the ability to control the release of water from the pool. This would then result in a higher likelihood that the upstream pool would increase to an elevation that would initiate failure of the dam. The operating gates are part of the original dam construction and are also over 70 years old. As previously stated, these six gates are caterpillar gates, each 7.0 feet wide by 15.0 feet tall and one emergency bulkhead of the same dimensions. The gates are riveted structural steel fabrication. Although some maintenance has been performed on the gates in the past, they are currently in poor condition and are in need of replacement.

3.2 Project Performance

3.2.1 Downstream Seepage

Historically, seepage (Figure 9) has exited the ground surface downstream of Bolivar Dam at pool elevations as low as 920 feet (<1-year return period). Seepage from the lower part of the embankment and natural terrace slopes above the rock toe has been observed to begin at a pool elevation of 930 feet (2.5-year return period); this is also the pool elevation at which flow from relief wells has first been observed. When the pool has risen above 930 feet, the quantity and exit elevation of seepage above the rock toe have both been observed to increase, and during the 2005 record pool (elevation of 952 feet; 94-year return period), excessive uncontrolled seepage exited the lower part of the embankment and terrace slopes above the rock toe between stations 49+00 and 51+00. The following paragraphs summarize observed performance of the dam during record events that the project has experienced.

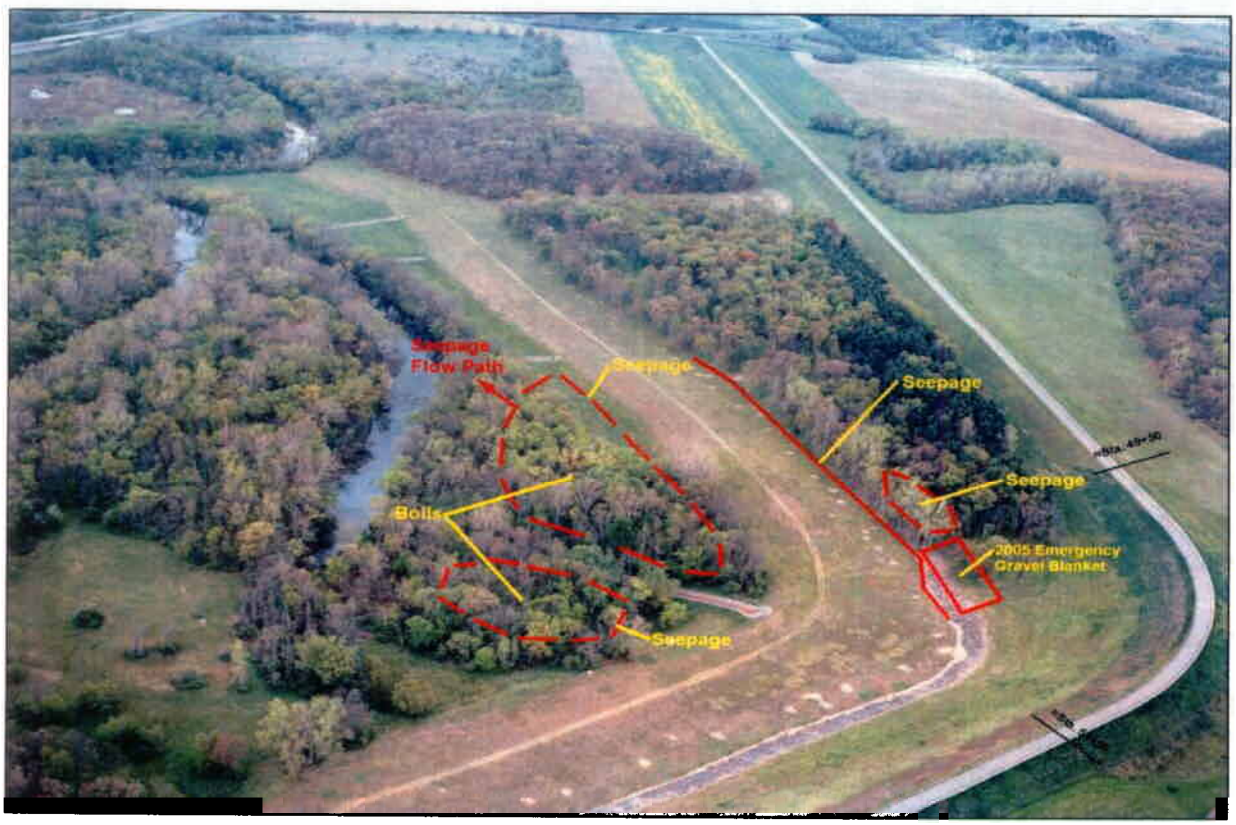

Figure 9. Seepage areas downstream of the Bolivar Dam main embankment.

3.2.2 Embankment Reanalysis Study

During an event with a 25-year return period (pool elevation of 944 feet) in 1969, numerous boils and seeps were observed downstream of the dam. Subsequently, the first periodic inspection report (1970) noted several project deficiencies and recommended that an embankment reanalysis study be conducted. The findings of the study, completed in September 1979, by Soil Testing Services, Inc., of Northbrook, Illinois indicated that the project did not have adequate factors of safety for seepage stability, and that the embankment in the vicinity of station 55+00 did not have adequate factors of safety for the (slope stability) rapid drawdown case. The above-mentioned embankment reanalysis study conclusions led to the construction of a downstream seepage blanket and toe drain, and the installation of 35 relief wells (completed in 1982), and the construction of an upstream stability berm (completed in 1989).

3.2.3 Relief Wells

The dam's thirty-five relief wells have been in operation since they were installed in 1982 as described above. Historic depth sounding, and flow data and static water level measurements versus pool elevation, are contained in Appendix H, Plates E75 to E85. The wells were initially sounded in 1983, and the maximum amount of sediment accumulation between 1983 and 2005 readings was 0.3 feet measured in W-13; the majority of wells have not shown sediment accumulation over time. The current monitoring schedule states all wells will be sounded annually or after pools of elevation greater than 930 feet. The monitoring schedule for flow measurements (or static water levels if wells are not flowing) has historically varied. Ideally, flows would have been measured continuously from the start to end of all past events; however, logistical- and funding-related challenges did not permit this level of data acquisition. Therefore, when evaluating past flow data it is necessary to consider when flows were measured during an event, relative to the trends of the pool elevation and adjacent piezometric data, in order to develop an understanding of relationships between well flows and pool elevation. The current monitoring schedule states well flows will be measured once every year when the pool elevation is less than 930 feet, weekly when the pool elevation is between 930 and 935 feet, once every two days when the pool elevation is between 935 and 943 feet, and daily when the pool elevation is greater than 943 feet.

The project wells have not normally flowed in the past until the pool elevation reaches 930 feet (2.5-year return period). Well flows were recently measured during May 2004 and September 2004 events, and shortly after the January 2005 record pool. At a pool elevation of 933 feet (3-year return period) in May 2004, wells W-15 through W-30 (stations 39+00 to 56+50) flowed. At a pool of 936 feet (3.5-year return period) in September 2004, wells W-05 to W-31 (stations 29+00 to 57+50) flowed. During February 2005, at a pool of 935 feet (which immediately followed the record pool of 952 feet), wells W-02 through W-32 (stations 25+00 to 58+50) flowed. Total flow from the relief well network on the February 2005 measurement date was more than 7500 gallons per minute (gpm). Further discussion of relief well flows for specific events as they relate to seepage model calibration is contained in Appendix H in this report. Conclusions regarding potential changes in well flow as a function of time (e.g. due to well deterioration or subsurface erosion feature enlargement) cannot be made due to the lack of adequate historic data. A review of static water levels does indicate that well static levels versus pool have not changed over time.

In addition to the lack of historic flow data, there are several additional shortcomings of the current relief well network. The first is that during future low-frequency events, flow data cannot be expected to be acquirable. This results from the downstream area being submerged beneath tail water during low-frequency events. The second shortcoming is the likely potential for well performance decline over time, coupled with the current lack of an implemented inspection, monitoring, and maintenance program. In general, wells suffer a loss in efficiency with time, for a variety of reasons such as clogging of screens and adjacent materials by fine particle infiltration, bacterial growth, and/or chemical incrustation. Continued biological activity in the wells can be expected based on recent observations of iron staining present in well outflow channels, and based on observations during past well rehabilitation work. The last maintenance of the wells occurred in 1994 when they were cleaned using a blended chemical heat treatment. At the start of that work, accumulated soft biomass ranging from several inches to a foot was present at the bottom of wells, and during air-lifting, large amounts of iron-rich biomass was removed. The third shortcoming of the well system is the lack of instrumentation (i.e. piezometers) positioned (e.g. adjacent to and between wells at select locations) to verify that depth and spacing design assumptions are adequate. As discussed subsequently in this report, the recommended remedial plan for the dam therefore includes specific measures to address existing concerns with the project's relief well system.

3.2.4 Left Abutment

Based on observations during past significant pools, it appears that water is entering coal/underclay/limestone units at approximate elevation 935 on the upstream face of the abutment. The water travels through the bedrock at the left abutment and exits from the cut slope just above the outlet tunnel/stilling basin as shown in Figure 7. This uncontrolled seepage has been observed at pools greater than approximate elevation 940 (approximately a 10-year return interval). During the high pool events in 1991 and 2005, uncontrolled seepage was observed out of the cut rock slope around the outlet works. The extent of the seepage path through the abutment bedrock cannot be verified; therefore, the future integrity of the abutment/embankment contact is in question. At this point, seepage has not been observed at the abutment/embankment contact during significant pools; however, this uncontrolled seepage is perceived as a deficiency. As part of a 2006 drilling program, two borings were drilled and two monitoring wells were installed to attempt to verify the existing seepage path with colored dye during high pool events.

The potential for unsatisfactory performance at seven pool elevations for the left abutment of the project has been evaluated through an expert elicitation approach as part of the Major Rehabilitation study. The resulting probabilities of unsatisfactory performance and performance levels are provided in Appendix I.

3.2.5 Operating Equipment and Gates

While it is expected that some of the individual machinery components will continue to function reliably for another fifty years, some of the components will not. The components suggested for rehabilitation are those that either currently have or will have a high probability of unsatisfactory performance over the next 10-20 years, many of which require minimal cost for considerable gain in reliability. The reliability and probability of unsatisfactory performance were computed based on Engineering Technical Letter, ETL 1110-2-560. The basic approach to determining the reliability was to use expert elicitation to approximate the average life of individual components. Once the average life is approximated, the age and usage of the equipment are then input into a spreadsheet that then computes the reliability (R(t)) of the equipment as well as the probability of unsatisfactory performance (F(t)). The reliability and unreliability also uses a reliability shape factor (Weibull Shape Factor) which accounts for failure rate of each individual piece of equipment which is also referred to the hazard function. Components with a high probability of unsatisfactory performance were suggested for rehabilitation, many of which are expected to become non-functional or exceed the expected life within the next 10 years. Currently the spreadsheet computations are still being finalized and the exact numbers produced are thought to be too high on the unreliability side. However, they were still used to show quantitative justification for the components selected for rehabilitation.

The primary concern with the gates is a gate(s) failure in the closed position where the gate(s) binds. As with the failure of the operating equipment, the gate(s) is unable to be opened, decreasing discharge capacity, and increasing the pool elevation to possible dam failure. Similarly, a gate(s) failure in the open position increases downstream discharge with possible flood damages, and potentially raises the Dover Dam pool to an unsafe level. Appendix K provides a summary of the inspection history of the gates and their degradation to their current condition and need for replacement, including photos of their current condition.

3.2.6 Record Event Observations (1991)

Subsequent to implementation of the above-described remedial measures, downstream boils and seeps were again observed in 1991, along with seepage from the lower part of the embankment and terrace slopes above the rock toe during a 64-year return period event (pool elevation of 949 feet). Field documentation from this event indicated, "Two areas of boiling flow were observed in the vicinity of the old stream channel (opposite approximate dam centerline station 60+00) about 150 feet downstream of the downstream sand and gravel blanket. There was water ponded to a depth of 15-inches and the boiling was surfacing in two places several feet apart. This flow was also clear and no evidence of sand or soil particle build-up was seen." Documented field observations also stated that, "In the area where the downstream stone protection ends for the main dam (right side – approximately station 48+00, near relief well #25), seepage was also noted. It seemed to flow from the small bench area above the stone and then flow over and into the stone, then on top of and through the sand and gravel blanket. Several small cave-ins of the blanket were noted at the base of the stone-sand and gravel interface where the flow had disturbed the sand from below." During inspection of the left abutment, four distinct areas were noted with water flowing from the hillside above the left side of the stilling basin. All seeps were at the same elevation and within 50 feet of each other. The flow was coming from the base of a row of large stone which parallels the stilling basin area and is about 30 feet from the top of the outlet portal. The estimated total flow of these areas was 150-200 gpm. Several fairly small seeps were flowing about 75-100 feet downstream from the four large seeps. This water was reportedly coming from the hillside and flowing in to the stone behind the left stilling basin wall. There were also two other small seeps noted at this time. One was a small trickle of water about 20 feet above the right tunnel portal and another flow (1-2 gpm) coming from the base of a small tree at the intersection of the hillside and concrete paving above the right tunnel portal. Although there are not extensive documented accounts from the 1991 event, observations during the event along with piezometric data indicated seepage stability concerns persisted at the project after implementation of remedial measures during the 1980's.

3.2.7 Record Event Observations (2005)

During the project's pool of record (Figure 8B) in January 2005 (elevation of 952 feet; 94-year return period), piezometric levels rose significantly and rapidly in response to increasing pool elevations, large relief well flows occurred, and numerous areas of uncontrolled seepage were observed. Contained in Appendix H, Plates B1 to B11, are photographs of the project which were taken during the event. Particularly near station 58+00, and in adjacent downstream regions, seeps beyond the seepage blanket produced large quantities of water with fine sand and silt being moved out of the ground. Heavy vegetation and the increasing tail water elevation prevented the monitoring of these regions during the entire event; submergence by tail water though could have somewhat improved stability against movement of material at these locations. Between stations 49+00 to 51+00, excessive uncontrolled seepage exited the lower part of the embankment and terrace slopes above the rock toe (Figure 6B). Based on the continued increase in seepage quantity and exit elevation during the event, a filter blanket (comprised of one foot of No. 57 river gravel overlain by one foot of No. 2 river gravel) was placed in this region as an interim emergency measure in an attempt to reduce risk. Evaluation of adjacent piezometric data trends versus pool elevation indicates that the initial causative pool for the conditions which prompted placement of this emergency filter was between 945 and 946 feet. After filter placement, the seepage quantity and exit elevation increased even further as the pool reached is maximum (Figure 6C). Between stations 36+00 and 43+00, pervasive seepage was observed at the toe of the natural terrace deposits, and evidence of sand having been moved out of the terrace deposits was apparent at the slope toe during and after the event (Figure 6D). At approximate pool elevation 944, project staff noted the seepage through the left abutment at four distinct locations. These seeps were approximately 50 feet from each other. Flow was exiting from the slope at the base of the lower limestone unit above the left side of the stilling basin. The estimated total flow of the seepages was approximately 150-200 gpm (Figure 7).

4.0 PROJECT HISTORY AND SUMMARY OF PREVIOUS WORK

4.1 Original Design Philosophy

The dam site is an outwash valley associated with the Wisconsin aged glaciation. The valley walls are one mile apart and are composed of bedrock rising to a maximum elevation of 1050 feet. The valley bottom soils on which the dam is built consist of pervious outwash deposits generally 150 feet thick. The top of bedrock is around elevation 750 feet in the central portion of the valley, and it increases to 875 feet near the dam's right abutment. Foundation soils extend up to depths of 230 feet below the crest of the dam. They predominantly consist of sand with variable amounts of silt, and several gravel strata with variable thicknesses and extents. Gravel strata consist of both poorly- and well-graded gravels. Highly pervious gravels are present extensively between approximate elevations of 910 and 935 feet from stations 5+00 to 52+50. They are directly exposed, along with underlying sands, in the upstream over-steepened slopes of the present Sandy Creek stream, and daylight on the terrace slope downstream of the dam. This results in a direct conduit for seepage through these materials along this project reach when a pool is retained behind the dam.

With reference to the above physical description, the dam design predated current methods for evaluating seepage and slope stability (e.g., no evaluations of exit gradients or uplift pressures, or slope stability analyses are in original design documents). The "dry" dam functions solely for flood control, and retains no permanent pool. Construction as-built drawings, typical sections, and subsurface data acquired prior to the dam's construction are contained in Appendix H, Plates A1 to A27; these provide a general overview of the project layout and subsurface. Also contained in Appendix H, Plates B1 to B37 are photographs of the dam which were taken during the 2005 record pool event and the 2006 periodic inspection, photographs showing historic seepage observations, construction of the downstream seepage blanket and relief wells, and construction of the upstream stability berm.

4.2 History

The timeline below summarizes the more significant studies, events, and remedial measures that have been performed at Bolivar Dam since 1969 or that will be performed:

1969 – Boils and seeps observed downstream of the dam during an event with a 25-year return period (pool elevation of 944 feet).
1970 – P.I. Report No. 1 – Seepage noted in area of original Sandy Creek channel.
1971 – Checked stability for major concrete structures.
1975 – Spillway Adequacy Study disclosed deficiencies in original spillway under revised hydrologic and hydraulic design criteria.
1979 – Completed Embankment Reanalysis Study.
1981-82 – Constructed toe drain, downstream pervious blanket and 35 Relief Wells.
1986 – Completed Dam Safety Assurance Study.
1989 – Correct Hydrologic Deficiency – Added parapet wall and widened spillway.
1989 – Added upstream stability berm.
1991 – High pool event (Elevation 950.14) - Seepage observed out of the cut rock slope above the outlet works, two areas of boils 150 feet downstream of the pervious blanket at Sta. 58+00, and seepage from the terrace slope area at approximately Sta. 48+00.
1991 – P.I. Report No. 5 – Recommended clearing overgrown area at abutment tie-in and left descending bank of widened spillway, and repair honeycombing in second pour areas on upstream side of gate slots.
1993 – Installed additional Piezometers near relief wells and in embankment.
1994 – Repairs to service gates (Long-term Deterioration).
1994 – Relief well rehabilitation.
1996 – P.I. Report No. 6 – Gates showing significant wear with an estimated 10 to 15 year service life before replacement is required.
2004 and 2006 – Performed additional drilling to further characterize subsurface conditions and install instrumentation.
2005 – Emergency Repair (Filter Blanket) during January Pool of Record, Elevation 951.65.
2005 – Screening for Portfolio Risk Assessment (SPRA) conducted – Bolivar Dam ranked as a Class II - Urgent (unsafe or potentially unsafe) project.
2006-07 – Performed seepage and slope stability analyses and determined the probability of unsatisfactory performance for various pool elevations.
2007-08 – Prepared IRRMP and began implementation of Interim Risk Reduction Measures.
2008 – Prepared plans for construction of downstream access road and seepage blanket.
2008 – Submit Major Rehabilitation Report to HQ for approval and funding.

4.3 Repairs and Modifications

Additional piezometers have been installed in numerous areas and at different time periods to monitor the dam and help in studying the potential underseepage problem. As previously mentioned, an embankment reanalysis study recommended construction of a downstream seepage blanket and toe drain, and the installation of 35 relief wells (completed in 1982), and the construction of an upstream stability berm which was completed in 1989. A DSA program disclosed deficiencies in the original spillway under revised hydrologic and hydraulic design criteria. This deficiency was corrected by doubling the width of the spillway to 540 ft. and raising the top of the dam by adding a 3.5 ft. concrete parapet wall which was also completed in 1989.

During the January 2005 pool of record (elevation of 952 feet; 94-year return period), a filter blanket (comprised of one foot of No. 57 river gravel overlain by one foot of No. 2 river gravel) was placed on the terrace at approximately station 50+00 as an interim emergency measure. Additional remedial measures planned pending approval of the IRRMP for Bolivar Dam include tree removal within 250 ft. of the toe of the dam, downstream access improvement, terrace seepage blanket augmentation, stockpiling additional granular material to be used during emergencies, and automation of critical instrumentation.

As a result of observation of the problematic seepage which occurred during the recent March 2008 flood event, it was determined prudent to implement several risk reduction measures or portions thereof in the summer of 2008. The measures proposed include the construction of a downstream access road to the terrace area of the dam, and augmentation of the downstream seepage blanket with a 6 ft. thick pervious material in an area of active boils. Also 900 ft. length of the terrace slope with active seeps will be covered with crushed aggregate filter material. Refer to Table 1 for a list of the historical maintenance and remedial measures conducted at Bolivar Dam.

4.4 Reduced Service Level

Until recommended rehabilitation is sufficiently completed to allow the dam to perform to its designed capability, the District has determined that it is in the public's interest to pursue implementation of an interim operating pool and regulation plan at elevation 949.0. The interim plan would require floodwaters to be released earlier than the current operating plan to prevent pool levels from exceeding unsafe elevations that would threaten the integrity of the dam. This will result in less flood waters being retained during larger rain events. The project target interim operating pool is a pool elevation to which the project would be managed whenever possible to provide the greatest acceptable level of safety to the dam. This pool management elevation is subject to change as Interim Risk Reduction Measures are deployed.

4.5 Summary of Historic Maintenance Costs

Table 1 below includes a description and cost for maintenance items and remedial measures performed at Bolivar Dam since 1971.

Description	FY	Cost (1,000)	P.I. RPT No.
Install piezometers in buried valley	1971	76	2
Install piezometers	1975	10	---
Install pervious blanket, toe drain and relief wells	1982	1,226	3
Inspect stilling basin (sounding only)	1981	0	3,5
Inspect stilling basin (by diver)	1987	0	3,5
Inspect stilling basin (by diver)	1989	0	3,5
Add upstream stability berm to dam, modify spillway, add parapet wall	1989	6,154	4,5
Install additional piezometers near relief wells and in embankment	1992	44	4,5
Install additional piezometers	1995	25	5
Sandblast and paint service gates (5)	1989	0	4,5
Clear trees from spillway (left lower end)	2002	4	5
Sandblast and paint the service bridge	1995	170	5
Make repairs to concrete u/s of service and emergency gate slots	1999	2	5
Repairs to service gates (long term) deterioration	Ongoing	60	5
Update conduits crack map	1993	1	6
Dam- Relief well rehabilitation	1994	75	6
Bolivar Dam – E-gage	2002	7	6
Clear underbrush dam terrace Area for Inspection Purposes	1998	---	5,6
Sandblast and paint service gates (6)	1988	---	4,5
Replaced windows in control structure	2001	22	---
Ditch liner in spillway along right side	2003	14	---
Repaired/rebuilt gate operators 2 and 5	2004	3	---
Seepage correction major rehab study	2005	550	---
Repaired and rebuilt #4 gate operator	2005	2	---
Stone stabilization at outflow	2005	2.5	---
Emergency stone stabilization at downstream seepage areas	2005	---	---
Repair/rebuild #3 Gate Operator in Control Structure	2006	1.6	---
Stockpile of Emer. Stab. Material on Project	2006	2	---
Installation of four piezometers downstream	2007	35	---
Install two test (dye) piezometers-dam road	2007	20	---
Interim Risk Reduction Study/Implementation	Ongoing	900	---
Partial Clearing of Trees – Terrace Area	2007	40	---
Construct downstream access road to terrace, install terrace slope and augment downstream seepage blanket	Planned 2008	1,600	

Table 1. Historical expenditures for remedial work at Bolivar Dam. Price level varies.

5.0 ECONOMIC CONSIDERATIONS

5.1 Federal Interest

The increase in reliability extends the project life resulting in deferred expenditures for replacement. Construction of the recommended plan would significantly reduce the probability of failure and the project benefits will be extended. Economic benefits are based on the following:

a) Increased reliability results in reduced future emergency action expenditures,
b) With the life of the project extended, there is no structure replacement cost in future funding streams; the replacement cost is considered deferred beyond the period of analysis;
c) Extending the life of the project results in additional average annual flood control and recreation benefits over the extended time frame;
d) With the potential for the high probability of failure reduced or eliminated, there are flood damage reduction and recreation benefits that would have been lost during the period of time necessary to accomplish the major repairs.

A probabilistic, risk based economic analysis was performed in conducting this Major Rehabilitation Evaluation for Bolivar Dam. Event trees were constructed in order to model the possibilities of occurrences of the dam, given its current condition, and their economic consequences. Life cycle analyses were used to consider the impact of these consequences over the 50-year period of analysis of this evaluation.

Major Rehabilitation guidance requires estimation of total economic costs and benefits of the base condition and alternative solutions. Guidance also requires identification of the recommended plan. The recommended plan will identify the optimum investment, both in terms of proposed actions and timing of proposed actions, given the risk and uncertainty identified during the study.

5.2 Base Condition

The base condition of the project is the current condition of the project components and their expected outcome if status quo practices of operation, maintenance and repair are continued. This condition is also referred to as the baseline, without project, existing condition, "fix-as-fails," or the "do nothing" alternative. It is the condition to which all other evaluated alternatives are compared in order to determine their effectiveness as an investment in the project. The Base Condition represents the minimal capital investment alternative in terms of doing preventative maintenance on the dam components. This method does not prevent significant impacts associated with unsatisfactory performance or impacts associated with catastrophic failures, but repairs components when they fail. If a project component fails under the base condition, it is assumed that emergency repairs will be made to the feature.

As previously described in Section 4.4, the District determined that it is in the public's interest to formally pursue implementation of an interim operating pool and regulation plan at elevation 949.0. The interim plan would require floodwaters to be released earlier than the previous plan in an attempt to reduce pool levels elevations that would threaten the integrity of the dam. For the purposes of the economic analysis, the base condition was defined as a fully functioning project to fully account for the negative economic consequences (i.e. lost flood protection benefits), or disbenefits in the event of unsatisfactory performance.

5.2.1 Effects of Bolivar Dam on Dover Dam

As previously stated, Bolivar Dam is one of 16 dams in the Muskingum River Basin that operate as a system to reduce flood damage. Bolivar is located directly upstream of Dover Dam on Sandy Creek, a tributary of the Tuscarawas River. Dover Dam is currently classified as a DSAC II dam. A Dam Safety Assurance (DSA) study for the Dover Dam was completed in July 2007. The DSA study recommends raising and anchoring the dam to allow for it to safely pass the 100% of the Probable Maximum Flood (PMF). The DSA report has been approved and construction is scheduled to begin in 2012.

The Dover pool stretches upstream to the toe of Bolivar Dam. Because of the close relationship between the two projects it is necessary to discuss the effects on Dover Dam in the event of a failure of Bolivar Dam.

5.2.1.1 Risk Based Model Considerations

For the purposes of the risk based model for this MRR it is assumed that for the first seven years of the analysis that Dover Dam would fail should the water elevation behind the dam reach 907. Therefore, Dover Dam would fail in the event of a Bolivar Dam failure, were that failure to cause the water elevation behind Dover Dam to exceed 907. After the first seven years it is assumed that Dover Dam has been fully repaired and able to withstand a Bolivar Dam failure.

5.2.1.2 Interim Operating Pool Considerations

To address public safety during high flow events the District has set a target Interim Operating Pool (IOP) for Dover Dam. This target elevation was determined through analysis of current engineering criteria and data. Initially the IOP was set at elevation 907, nine feet below the spillway crest of 916. In March of 2008 bar anchors were installed at Dover Dam as part of the Interim Risk Reduction plan. The addition of the bar anchors enabled the District to increase the IOP from elevation 907 to elevation 910[1].

5.3 With Rehab Condition

The Rehab condition of the project is the proposed future condition of the project components and their expected outcome if the proposed alternative is adopted. This condition is also referred to as preferred alternative or recommended plan.

A rehabilitated Bolivar Dam would perform to its originally authorized level, protecting the downstream area from significant flooding over the life of the project.

5.4 Risk Based Model

[1] The bar anchors at Dover Dam were install subsequent to the conclusion of the Risk Based modeling effort for the Bolivar project. The model assumes that Dover Dam would fail at the original IOP level of 907.

The economics of the project were evaluated using Corps procedures as specified in EP 1130-2-500 dated 27 December 1996 entitled "Project Operations – Partners and Support 58 (Work Management Guidance and Procedures", Appendix B: Rehabilitation Evaluation Report).

The analysis was performed using risk and reliability analysis. This was accomplished by developing a life cycle simulation model that considered the reliability of the project and the expected consequences of unsatisfactory performance. The core logic of the model is based on the possible sequences of events as shown on an event tree that lists the key factors in the analysis and displays the relationship between the factors. A sample of an event tree for the Bolivar project is provided as Figure 10. See Appendix B for full set of event trees used for analysis.

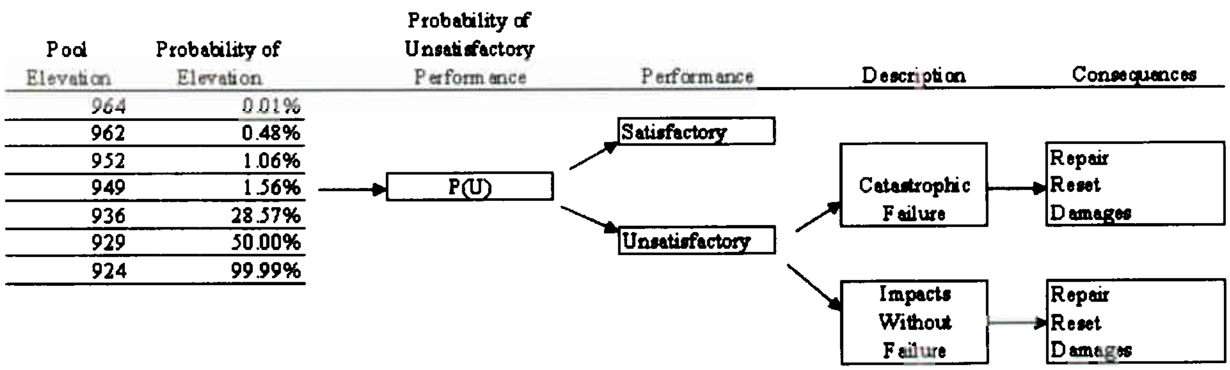

Figure 10. Bolivar event tree.

The analysis then focuses on the quantification of values for each of the factors listed on the event tree, and on the development of the simulation model which mathematically links the factors. The model is then run for the baseline condition and for alternative future conditions with the difference in results being a function of differences in the input values assigned to the factors, such as the probability of unsatisfactory performance. The outputs are used to compute the benefits of alternative plans, which are then compared to the costs of the alternatives to determine economic feasibility and to identify the National Economic Development (NED) plan.

Excel software with the @RISK add-on feature was used for the programming. The model was documented and reviewed. Based on the review it was submitted for certification as a regional model but the process for certification is still underway. For additional information on the Risk Based Model please refer to Appendix B of this report.

6.0 ENVIRONMENTAL CONSIDERATIONS

6.1 Existing Conditions & Impacts of Alternatives

As mentioned in Section 1.4, documentation of the existing conditions for this report assumes the completion of the currently proposed IRRMs at the Bolivar Dam. The IRRMs were developed in accordance with Corps Policy as prescribed in EC 1110-2-6064 (Interim Risk Reduction Measures for Dam Safety, 2007). The measures developed are intended to be feasible measures that can be implemented in a timely fashion in order to minimize the exposure to risk prior to the major rehabilitation of Bolivar Dam. The proposed IRRMs for Bolivar include numerous maintenance and administrative actions at the dam site, the majority of which do not require evaluation and documentation under the National Environmental Policy Act (NEPA). The Bolivar Interim Risk Reduction Plan (IRRMP) is included in Appendix M of this report.

An Environmental Assessment (EA) is underway to evaluate and consider the effects of all measures proposed in the IRRMP, as required by NEPA. All measures included in the IRRMP measures are scheduled to be completed by close of 2009. Refer to Appendix M. for the IRRMP.

During the plan formulation process, an array of alternative measures was considered and documented in the Section 8.0, Alternative Formulation and Evaluation. Most of these measures were eliminated from further consideration during the initial screening process as they were not cost effective or did not adequately meet planning objectives (See Section 8.3 for objectives) of the study. Consideration of the environmental effects was inherent in the screening process. The final array of alternatives is listed below:

- Partial Depth/Length Concrete Seepage Barrier (Main Embankment)
- Seepage Cutoff Wall (Left abutment)
- Combination (Main Embankment + Left Abutment)
- No Federal Action or Base condition

As the environmental effects associated with the Main Embankment and Left abutment alternatives are encompassed within the combined alternative, this alternative (alternative plan) will be used for comparison purposes to the No Action Alternative.

6.1.1 Land Use

With the exceptions of the existing dam and associated facilities, most land at the site is not developed and includes mowed/maintained areas, agricultural fields, forest, shrub, and wetland habitats. Recreational hunting is allowed in the project area, except within 200 yards of a structure (the earthen dam excluded). The 0.10 acre of forested habitat that would be affected is not available to hunting because of its proximity to a structure; therefore there would be no impacts to recreational hunting. As the alternative plan includes actions to augment or repair existing structures, implementation of the alternative plan would not affect land use in the project area.

Under the No Action alternative the areas would remain in their current condition and the current land use would remain.

6.1.2 Physiography, Geology, Soils and Prime Farmland

The project area lies within the unglaciated region of Ohio. It is located within the Muskingum-Pittsburgh Plateau region of the Appalachian Plateaus physiographic province. Topography of the area can best be described as a moderately-high to high relief dissected plateau having broad major valleys that contain outwash terraces and tributaries with lacustrine terraces (Brockman 1998). Underlying bedrock consist of Allegheny and Pottsville Groups, undivided of Pennsylvanian Age (Slucher 2002).

The *Soil Survey of Stark County, Ohio* (Christman 1971*)* and the *Soil Survey of Tuscarawas County, Ohio* (Waters 1986) depict six soil series within the study area. Relevant information for the mapped soil types is included below.

- **Conotton -** This series consists of well-drained, level to steep soils that occur in outwash areas. These soils contain a large amount of gravel throughout. Conotton is not a hydric soil, but is an indicator of prime farmland of local importance.
- **Chili -** The Chili series consists of well-drained, level to steep soils that occur on broad stream terraces, outwash plains, and kames. These soils formed in glacial outwash of Wisconsin Age. Chili is not a hydric soil, but is considered an indicator of prime farmland.
- **Melvin –** The Melvin series consists of deep, poorly drained, moderately permeable soils that formed in silty alluvium on floodplains. Slopes range from 0 to 3 percent. This soil is hydric, and is an indicator of prime farmland if drained and protected from further flooding.
- **Pits, gravel –** This map unit consists of surface mined areas from which sand and gravel have been removed for use in construction. The pits are commonly on outwash terraces and in areas of the Chili, Conotton, and Wheeling soils, which are underlain by glacial outwash. This soil is not considered hydric nor an indicator of prime farmland.
- **Udorthents –** These soils are in areas of cut and fill, mainly in construction areas along highways, in urban areas, and near dams in the Muskingum Watershed Conservancy District. This soil is not considered hydric or prime farmland.
- **Wayland silt loam (Wd)** - A nearly level, very deep, poorly drained soil. Typically, the surface layer is silt loam about 2 inches thick. The surface layer has a high content of organic matter. The slowest permeability is moderate. It has a high available water capacity and a low shrink swell potential. The soil is frequently flooded and is not ponded. The top of the seasonal high water table is at 3 inches. The soil contains a maximum amount of 1 percent calcium carbonate. This soil is hydric.
- **Wheeling –** The Wheeling series consists of well-drained, level to steep soils on stream terraces, outwash plains, and kames. These soils formed in silt loam glacial material of Wisconsin age that is underlain by gravelly and sandy outwash. This soil is not considered hydric. Wheeling soils are considered an indicator of prime farmland.

Specific soil types within the areas of impact of the alternative plan include Melvin silt loam, Connotton gravelly loam and Chili gravelly loam. Only Melvin silt loam is considered prime if the area is drained or not frequently flooded. Currently, the areas with this soil type is predominately wetland type soils, therefore the area is not considered prime farmland. Therefore, no impact to prime farmland is expected with implementation of the proposed measures. Soil maps are included in the wetland delineation report found in Appendix C.

6.1.3 Fish and Wildlife Resources

Direct and indirect observations of wildlife resources in the area include the following: white-tailed deer (*Odocoileus virginianus*) tracks, beds, trails, and scat, squirrel nests, crayfish chimneys, woodpecker holes, potential Indiana bat (*Myotis sodalis*) habitat, moles, other small rodents, rabbit scat, water fowl, and frogs.

The wildlife resources present in the area are fairly common and generally tolerant of human disturbances such as those related to this project. Implementation of the alternative plan would result in the loss of less than 0.10 acres of forested habitat in the area of the left abutment concrete cutoff wall. However, as the observed species are relatively mobile, direct mortality would be expected to be minimal as fauna could move to similar adjacent habitat which is readily available in areas immediately adjacent to the areas to be impacted. For this assessment it is assumed that this area would remain cleared of woody vegetation. However, because this area is small, and that the Bolivar project area encompasses about 600 acres much of which has forest cover, any impacts from this clearing on wildlife resources would be minor.

Under the No Action alternative the forested area would continue to mature. This would provide improvements in habitat for some species. The increased risks of dam failure during extreme flood events would remain. The effects of dam failure on fish and wildlife resources are largely unpredictable. It is likely that in a failure scenario, the Dover Dam would have a significant pool. In this case, the pool would greatly curtail any erosion and scouring from increased discharges, and thus reduce effects on fish and wildlife resources. Predicting effects on these resources during a dam failure scenario would be speculative and therefore not provide meaningful analysis.

6.1.4 Endangered Species

The USFWS maintains a list of federally endangered, threatened, proposed, and candidate species in Ohio. This list, last updated in June 2007, lists Stark and Tuscarawas Counties as being in the range of four species. Information on these species is summarized below.

- **Indiana bat** (*Myotis sodalis*) **(endangered)** - Indiana bats hibernate during winter in caves or, occasionally, in abandoned mines. After hibernation, Indiana bats migrate to their summer habitat in wooded areas where they usually roost under loose tree bark on dead or dying trees. During summer, males roost alone or in small groups, while females roost in larger groups of up to 100 bats or more. Indiana bats also forage in or along the edges of forested areas and riparian areas along streams and rivers.
- **Clubshell** *(Pleurobema clava)* **(endangered)** - This mussel prefers clean, loose sand and gravel in medium to small rivers and streams. The clubshell mussel will bury itself in the bottom substrate to depths of up to 4 inches. Reproduction requires a stable, undisturbed habitat and a sufficient population of fish hosts to complete the mussel's larval development. Extirpated from Alabama, Illinois, and Tennessee, it occurs today in portions of only 12 streams. Reasons for its decline in the upper Ohio watershed have

been principally due to pollution from agricultural run-off and industrial wastes, and extensive impoundments for navigation.

- **Eastern Massasauga** (*Sistrurus catenatus catenatus)* **(candidate) -** Throughout much of its range in the eastern United States, massasauga rattlesnakes are found in wet prairies, sedge meadows, and early successional fields. Preferred wetland habitats are marshes and fens. They avoid open water and seem to prefer the cover of broad-leafed plants, emergents, and sedges. Natural succession of woody vegetation is a leading cause of recent habitat deterioration throughout its range. Intensive management to retard woody vegetation growth is necessary to maintain suitable habitat conditions.

The bald eagle is no longer a federally listed species. When the bald eagle was listed in 1967 as endangered under the forerunner of the Endangered Species Act, there were barely 400 nesting pairs in the entire lower 48 states. Now there are more than 9,700 nesting pairs in the United States. On July 6, 1999, the USFWS proposed de-listing the bald eagle (64 FR 36453), and on June 28, 2007, the USFWS de-listed the bald eagle from protections of the Endangered Species Act (72 FR 37346). The bald eagle remains protected under the Bald and Golden Eagle Protection Act and the Migratory Bird Treaty Act.

Field observations and coordination with State and Federal natural resource agencies concluded Bald eagles and Eastern massasaugas are not in the project area therefore no impacts to these species are anticipated. No small rivers, streams would be affected by the alternative plan; therefore no impact to the clubshell mussel would occur.

Implementation of the alternative plan would result in the loss of less than 0.10 acres of forested habitat in the area of the left abutment concrete cutoff wall. To avoid impact to Indiana Bat, clearing activities would be limited to winter months (September 15 to April 1) while the Indiana bat is in hibernation. Extensive informal coordination with the USFWS has taken place and will continue throughout the study and design phases pursuant to full compliance with the Fish and Wildlife Coordination Act.

Under the No Action alternative habitat types would be expected to change through natural succession. As forest matures, it would be expected that habitat for the Indiana bat may also improve. Increased risks of dam failure during extreme flood events would remain. However, it is likely that in a failure scenario there would be a substantial pool impounded by Dover Dam. This pool would likely reduce velocities below Bolivar significantly and buffer effects to habitats.

<u>6.1.5 Wetlands</u>

During the consideration of environmental effects of the IRRMP, a jurisdictional evaluation for "waters of the U.S.," including wetlands, for the Bolivar Dam located in Bolivar, Tuscarawas County, Ohio was conducted in November 2006. Current criteria require positive indicators of hydrophytic vegetation, wetland hydrology, and hydric soils for an area to be considered a jurisdictional wetland. Three areas totaling 1.92 acres were delineated within the study area. The complete Wetland Delineation report is included in Appendix C. A summary of the delineated wetland areas is presented below.

- Three forested wetlands consisting of 0.04 acre, 0.17 acre, and 1.71 acres, respectfully, and 108 linear feet (lf) of intermittent stream channel were identified as a result of the investigation. One of the three wetlands, Wetland 2, has a surface connection to other "waters of the U.S." (i.e., Sandy Creek), while Wetlands 1 and 3 did not appear to have a surface connection to any other surface waters. Assessment of the wetlands using the Ohio Rapid Assessment Method (ORAM) scored Wetlands 1 and 3 as Category 1 wetlands and Wetland 2 as a Category 2 wetland.

IRRM's planned in the near future include impact to all three wetlands in the form of tree removal. Trees and root balls are to be removed with the implementation of this action. Coordination with the Ohio Department of Environmental Protection is ongoing to determine appropriate mitigation for impacts associated with the Interim Risk Reduction Measures.

A portion of the alternative plan, the placement of granular seepage blanket, would be placed within the wetland areas to be affected by the tree removal planned as an IRRM (Figure 12). However, the IRRM EA assumes mitigation for impacts for the entire 1.92 acres of wetlands, which would be accomplished through participation in a mitigation bank[2]. Therefore, the IRRM EA addresses all impacts to these wetlands. No further mitigation is required from the proposed action.

Impacts to wetlands under the No Action alternative are largely unpredictable. Only in the event of a catastrophic failure of Bolivar Dam simultaneous with little impounding of a pool behind from Dover Dam would impacts to the wetlands be expected to occur.

6.1.6 Floodplain

Sandy Creek is dammed to the south of the project area, and flows north, out of the dam west of the project area. Portions of the project area lie within the Sandy Creek floodplain. According to the Flood Insurance Rate Map (FIRM) prepared by the Federal Emergency Management Agency (FEMA), lands adjacent to Sandy Creek and most of the project area are within the 100-year floodplain. The FEMA map is included within the wetland delineation Report Included in Appendix C. Environmental Assessment Supporting Documentation. The proposed action would no impacts floodplains because there would be no encroachment. .

The alternative plan and the No Action alternative would not impact the Sandy Creek floodplain.

6.1.7 Vegetation

Vegetation in the area is associated with habitats that include mature coniferous and deciduous forest, shrubs, and wetlands. During the field investigations, 30 species of trees were identified within the project area with sizes ranging from saplings to mature trees of almost 30 inches

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[2] The Water Resources Development Act of 2007 (PL110-114-NOV. 8,2007) states that "In carrying out a water resources project that involves wetlands mitigation and that has impacts that occur within the service area of a mitigation bank, the Secretary. where appropriate, shall first consider the use of the mitigation bank if the bank contains sufficient available credits to offset the impact and the bank is approved in accordance with the Federal Guidelines for the Establishment, Use and Operation of Mitigation Banks (60 Fed. Reg. 58605) or other applicable Federal law (including regulations)."

diameter at breast height (dbh). Woody vines, ferns, grasses, sedges, and numerous species of herbaceous forbs were also identified during the field investigation. Herbaceous plant height ranged from basal leaves to over 7 feet tall.

All floral species present in the area are considered common, and individual species as a whole will not be greatly impacted. However, implementation of the alternative plan would result in the clearing of approximately 0.10 acres resulting in minimal and insignificant loss of forested habitat.

No construction related effects on vegetation would occur with the No Action Alternative, however increased risks of dam failure during extreme flood events would remain. The effects of dam failure on vegetative resources are largely unpredictable. It is likely that in a failure scenario, the Dover Dam would have a significant pool. In this case, the pool would greatly curtail any erosion and scouring from increased discharges, and thus reduce effects vegetation. Predicting effects on these resources during a dam failure scenario would be speculative and therefore not provide meaningful analysis.

Detailed information on vegetation, including botanical surveys is included in Appendix C, Environmental Assessment Supporting Documentation.

6.1.8 Regulated Hazardous Contaminants

In accordance with U.S. Army Corps of Engineers environmental policy, a Limited Phase I HTRW investigation around the dam site was completed in March 2008. Results of the Phase I indicate no HTRW concerns are anticipated on the lands affected by the alternative plan. Therefore, no effect would occur as a result of the alternative plan. No further HTRW investigations are recommended for this area.

With the No Action Alternative increased risks of dam failure during extreme flood events would remain. Should dam failure occur when there is little impounded waters behind Dover Dam, there would be an increased potential for release of stored HTRW substances resulting from the destruction of structures (i.e. fueling stations, manufacturing companies) located below the dam. However, it would be expected that a substantial pool would exist behind the Dover Dam during a flood event that would induce failure of Bolivar Dam. In this case, only very localized scour (at the dam) would be expected and therefore little probability of releases of hazardous materials as a result of the failure.

Refer to Appendix L, Hazardous, Radioactive, and Toxic Waste for additional information.

6.1.9 Cultural Resources

An initial archaeological survey was completed on federally owned land managed by the Huntington District at Atwood, Beach City Lake, Bolivar Dam, Charles Mill Lake, Clendening Lake, Dillon Lake, Dover Dam, Mohawk Dam, Mohicanville Dam, Pleasant Hill Lake, and Senecaville Lake in 1982 (Brown 1982). The data produced from this survey and other surveys conducted within the basin was compiled and documented within the Corps Historic Properties Management Plan for the Muskingum Basin. Three databases maintained by the Ohio Historic

Preservation Office were used for this inventory: the Ohio Archaeological Inventory (OAI), the Ohio Historic Inventory (OHI), and the National Register of Historic Properties (NRHP). The inventory recorded a number of prehistoric archaeological sites within and near the Bolivar Project.

Because of the location of the proposed project, there is a high probability that archaeological sites will be impacted by the proposed actions. An archaeological reconnaissance was completed in 2008 and a Phase I archaeological survey is currently underway. Whether further work will be required to document sites or mitigate adverse effects will not be known until survey is completed in July 2008. The Corps has engaged in consultation with the State Historic Preservation Office (SHPO), pursuant to the regulations (36 CFR Part 800) implementing Section 106 of the National Historic Preservation Act (NHPA). Any necessary surveys, testing, evaluation, effect determination and mitigation planning will be performed prior to implementation of the selected alternative. Coordination with the State Historic Preservation Office is ongoing and will be maintained throughout this process to ensure full compliance with Section 106 of the NHPA.

Visual effects from the proposed action would be minor because all features would be buried and vegetated.

Under the No Action alternative, no construction related impact to cultural resources would occur. However, risk of dam failure would persist. The effects of dam failure on downstream resources are largely unpredictable. It is likely that in a failure scenario, the Dover Dam would have a significant pool. In this case, the pool would greatly curtail any erosion and scouring from increased discharges. Predicting effects on these resources during a dam failure scenario would be speculative and therefore not provide meaningful analysis.

6.1.10 Scenic Rivers

Sandy Creek is not designated as a State Scenic River. Moreover, correspondence with the Ohio Department of Natural Resources (ODNR) revealed that there are no existing or pending state or national scenic rivers are present in the project area. No impact to Scenic Rivers would occur with the alternative plan or the No Action Alternative. A copy of the ODNR correspondence is included in Appendix C, Environmental Assessment Supporting Documentation.

6.1.11 Air Quality

The USEPA is required to set air quality standards for pollutants considered harmful to public health and welfare. The Primary National Ambient Air Quality Standards (NAAQS) set limits to protect public health, including the health of sensitive populations such as asthmatics, children, and the elderly. Secondary standards set limits to protect public welfare, including protection against decreased visibility, and prevention of damage to animals, crops, vegetation, and buildings. These standards have been established for the following six principal pollutants, called criteria pollutants (as listed under Section 108 of the CAA):

- Carbon monoxide (CO);
- Lead (Pb);

- Nitrogen dioxide (NO2);
- Ozone (O3);
- Particulate matter, classified by size as follows:
- An aerodynamic size less than or equal to 10 micrometers (PM10);
- An aerodynamic size less than or equal to 2.5 micrometers (PM2.5);
- Sulfur dioxide (SO2).

Stark County, Ohio is considered in nonattainment for PM2.5. Additionally, Stark County was redesignated in attainment for Ozone with an approved area maintenance plan in 2007. Stark County is listed as in attainment for the remaining criteria pollutants, and Tuscarawas County is in attainment for all six pollutants. In areas that are in nonattainment or redesignated in attainment with a maintenance plan, the Clean Air Act requires that the Federal government make a conformity determination to assure that their actions would conform to the State Implementation Plan for that pollutant.

The alternative plan would involve construction equipment including two diesel excavators, two diesel dozers, and three off-highway dump trucks. The total PM2.5 emissions from these sources is estimated to be 0.71 tons/year using 2008 emissions factors from the USEPA NONROAD model. Also using this data, estimates for Ozone would be 14.57 tons/year of NOx and 0.86 tons/year of VOC. The alternative plan is therefore exempt from making a conformity determination, since estimated emissions from construction equipment would be far below the *de minimis* standards of 100 tons/year, which are the minimum threshold for which a conformity determination must be performed. Therefore, no significant impacts to air quality would be expected from the proposed action.

No impact to air quality would occur with the No Action Alternative.

6.1.12 Noise

No significant noise generators are located within the project area. The project area is near an interstate highway and a municipal landfill. Existing noise sources include interstate and local traffic, farming equipment, and landfill activities.

Under the proposed action, noise in the area would be generated during construction of the alternative plan. The closest receptors to the construction area are homes in a residential community approximately 0.3 miles from the area in which construction would be occurring. Due to substantial distance from receivers, intermittent nature of noises and additional buffering from the rolling topography and vegetation, noise impacts of the alternative plan would not be insignificant.

No impacts due to noise would occur with the No Action Alternative.

6.1.13 Socioeconomic Profile

Stark County occupies about 581 square miles and has an estimated population of 380,575. The City of Canton is the county seat. Although over 75 percent of land use is either forested, cropland, or pasture within Stark County, manufacturing is the largest employer on a countywide basis, accounting for 18 percent of total employment. Healthcare and social assistance is the second largest employment sector, followed by local government and retail. Major manufacturers include: Precision Castparts Corporation, Republic Engineered Products, and the Timken Company. Aultman Hospital; Canton City Board of Education; Fisher Food, Inc.; General Electric Company; Mercy Medical Center; and Wal-Mart Stores, Inc. are other principal employers in the county. The county unemployment rate as of the year 2006 was 5.8 percent, a little higher than the state rate of 5.5 percent. Per capita income as of 2005 was about $29,236.

Approximately 83 percent of the population includes high school graduates or individuals with more advanced degrees. About 15 percent of the county population is 65 or older. Since the early 1990s, more people have been migrating out of Stark County than into the county.

Tuscarawas County occupies about 571 square miles and has an estimated population of 91,766. The City of New Philadelphia is the county seat. Although over 90 percent of land use is either forested, cropland, or pasture within Tuscarawas County, manufacturing is the largest employer on a countywide basis, accounting for 22 percent of total employment. Healthcare and social assistance is the second largest employment sector, followed by local government and retail. Major manufacturers include: Alamo Group/Gradall Industries, Allied Machine & Engineering, Sanwa Shutter Corp/Genie Company, Smurfit-Stone Container Corporation, and Zimmer Holdings Inc. Dover City Board of Education, New Philadelphia City Board of Education, Union Hospital, and Wal-Mart Stores, Inc. are other principal employers in the county. The county unemployment rate as of the year 2006 was 5.1 percent, a little lower than the state rate of 5.5 percent. Per capita income as of 2005 was about $25,461.

Approximately 80 percent of the population includes high school graduates or individuals with more advanced degrees. About 15 percent of the county population is 65 or older. Since 2004, more people have been migrating out of Tuscarawas County than into the county.

Under Executive Order (EO) 12898 "Federal Actions to Address Environmental Justice in Minority Populations and Low Income Populations," federal agencies are directed to identify, address, and avoid disproportionately high and adverse human health or environmental effects on minority and low income populations. Minority populations are extremely low in Stark and Tuscarawas Counties compared to the predominantly Caucasian population (90.3 percent and 97.7 percent, respectively), according to the Ohio Department of Development (ODOD). The percentage of family income below the poverty level is 6.8 percent and 7.2 percent (respectively) for 1999.

As the repairs of the project would provide benefits to the downstream areas regardless of ethnic or socioeconomic status, the project would not disproportionately affect low-incomes or minority populations. Moreover, the project would not create adverse human health or environmental effects. The alternative plan is in compliance with EO 12898.

The No Action alternative would have no effect on Socioeconomics of the area. However, risk of dam failure would persist. The loss of flood damage reduction provided by Bolivar Dam would adversely affect the socioeconomic values of those communities currently afforded that protection.

6.1.14 Aesthetics

Proposed activities will occur in an area that is largely undeveloped, with the exception of the existing dam and associated USACE facilities, remaining areas are characterized by natural habitats including forests, shrub areas, and wetlands. The majority of structures proposed to be constructed will be underground (i.e. seepage cutoff walls). The visible portions of the alternative plan would consist of placement of an upstream impervious blanket and granular seepage blanket below the dam. Both of these features would be seeded and maintained once construction is complete and would be complementary to the existing features. Therefore, there would be no significant effect to aesthetics with implementation of the alternative plan.

With the No Action Alternative, there would be no construction related adverse effect on aesthetic resources.

6.1.15 Transportation and Traffic

Major roads surrounding the Bolivar Dam area include Interstate 77 running along the western boundary and Gracemont Street running along the northern boundary. Gracemont Street has large truck traffic associated with the landfill operations on the north side of the street. Lexy Road runs along the crest of the dam and will be closed for at least one year during construction. The effects of this road closure are considered minor due to the availability of several alternative routes for local traffic to access affected areas.

Transportation or traffic on Interstate 77 would not be noticeably affected by the proposed action. Local routes including Gracemont Street and Lexy Road would at times have temporary traffic increases during construction, specifically during mobilization and demobilization of construction equipment. There would also be increases in construction related traffic on local roads due to transportation of materials to the project for construction of the seepage barriers and impervious blanket material. This traffic would consist of trucks, workers' personal vehicles and construction equipment. Debris and soil may deposit on roadways from construction vehicles, creating additional safety hazards as well as annoyance to residents.

A traffic maintenance plan would be prepared by the construction contractor prior to construction, in coordination with local jurisdictions and emergency service providers. Traffic detours, road closings, road cleaning procedures and other necessary traffic maintenance measures would be prominently posted and also provided to local newspapers in advance.

The No Action Alternative would result in no Transportation and Traffic related impacts. However, the likelihood of failure of the dam would remain. In any dam failure scenario Lexy Road could be severed by a breach in the dam.

6.1.16 Cumulative Effects

Cumulative effects are "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such actions" Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time (40 CFR Part 1508.7 Council on Environmental Quality [CEQ] Regulations).

The cumulative effects analysis qualitatively presented below is based on the potential effects of the proposed project when added to similar impacts from other projects in the region. An inherent part of the cumulative effects analysis is the uncertainty surrounding actions that have not yet been fully developed. The CEQ regulations provide for the inclusion of uncertainties in the analysis and states that "when an agency is evaluating reasonably foreseeable significant adverse effects on the human environment….and there is incomplete or unavailable information, the agency shall always make clear that such information is lacking" (40 CFR 1502.22). The CEQ regulations do not state that the analysis cannot be performed if the information is lacking.

The proposed project may be considered as a modification of the existing dam. The effects as discussed beforehand are localized and minor. In scoping past present and future actions, the spatial, or geographic, limits for analyses of actions that may contribute cumulative with the proposed action would appropriately be limited to the dam and vicinity. Past actions that may contribute to cumulative effects would be construction of the parapet wall conducted as part of the Dam Safety Assurance Program, implementation of certain IRRMs, and the total of improvements that have been made to the Bolivar project since original construction (e.g. additional facilities). No reasonably foreseeable future actions that would have similar impacts as the proposed action were identified. In scoping cumulative effects issues, no resources were identified as having a potential to be significantly affected.

6.2 Environmental Requirements and Protection Statutes

The chart below identifies federal statutes, state, Corps and local regulations applicable to the proposed action. Throughout the process of developing this assessment, coordination pursuant to the Fish and Wildlife Coordination Act and Endangered Species Act has been maintained with the US Fish and Wildlife Service and appropriate state resource agencies (*See Appendix C)*

Federal Statues	**Recommended Action**
Archeological and Historic Preservation Act as Amended, 16 U.S.C. 469, et seq.	FC [3]
Clean Air Act As amended, 42 U.S.C. 7401, et. seq.	FC
Clean Water Act (Federal Water Pollution Control Act) As amended, 336 U.S.C. 1251, et seq.	FC [4]
Endangered Species Act As amended, 16 U.S.C. 1531 et seq.	FC
Federal Water Project Recreation Act	NA

[3] The Corps is in the process of evaluating effects in close coordination with the State Historic Preservation Office. Any necessary surveys, testing, evaluation, effect determination and mitigation planning will be performed prior to implementation of the selected alternative. Coordination with the State Historic Preservation Office will be maintained throughout this process to ensure full compliance with Section 106 of the NHPA.

[4] There are no discharges to waters of the United States associated with the proposed action; therefore, Section 404 of the CWA does not apply.

As amended, 16 U.S.C 661, et seq.	
Fish and Wildlife Coordination Act	FC
As amended, 16 U.S.C. 661 et seq.	
Land and Water Conservation Fund Act	FC
As amended, 42 U.S.C. 4601-4601-11, et. seq.	
National Environmental Policy Act	FC
As amended 42 U.S.C. 4321, et. seq.	
National Historic Preservation Act	FC
As amended, 16 U.S.C. 470a, et seq.	
Rivers and Harbors Act, 33 U.S.C. 401, et seq.	NA
Rivers and Harbors Act, 91 U.S.C. 122, et seq.	NA
Watershed Protection and Flood Prevention Act	FC
16 U.S.C. 1001, et seq.	
Wildlife and Scenic Rivers Act	NA
As amended, 16 U.S.C. 1271, et seq.	
Comprehensive Environmental Response, Compensation	FC
And Liability Act, 42 U.S.C. 9601, et seq.	
EXECUTIVE ORDERS, MEMORANDA, ect.	
Floodplain Management (E.O. 11988)	FC
Protection of Wetlands (E.O. 11990)	FC
Environmental Justice (E.O. 12898)	FC
Farmland Protection Policy Act, PL 97-98, 7CFR 658	FC
STATE, LOCAL and CORPS POLICIES	
Hazardous, Toxic and Radioactive Waste (HTRW)	FC
Guidance, ER 1165-2-132	

NOTE: FC – Full Compliance
PC – Partial Compliance
NA – Not Applicable

6.3 Coordination and Correspondence

Coordination with various federal, state and local agencies was undertaken during the preparation of this report (See Appendix C for correspondence). The Bolivar Dam Major Rehabilitation Report and EA will be made available to environmental resource agencies, both federal and state, as well as the general public and other interested agencies, groups and individuals for a 30-day review period.

A notice of availability will be prepared and will be published in the local newspapers including The Massillon Independent, and the Times Reporter, concerning this document. Comments received during the 30-day review period will be considered in the Final EA.

7.0 ENGINEERING CONSIDERATIONS

7.1 Hydrology and Hydraulics

Bolivar Dam is located 8.6 miles upstream of Dover Dam; therefore Dover controls most of the outflow from Bolivar. During large events, Dover will back water upstream onto the downstream toe of Bolivar dam. The regulation of the available storage above Dover provides substantial flood protection along the Tuscarawas River and also aids in providing flood protection along the Muskingum and Ohio Rivers. Due to the interaction of these two projects, hydrology and hydraulics studies were conducted to develop inflow hydrographs for use in analyzing the performance of Bolivar Lake under four pre-determined conditions. 1.) Bolivar Fixed - Dover Fixed 2.) Bolivar Fixed - Dover Failed, 3.) Bolivar Failed - Dover Failed, 4.) Bolivar Partially Failed - Dover Fixed). The fixed condition refers to restoring the project to the original operating condition while the failed condition refers to letting the project wash totally out at a pre-determined elevation. The breach plan for Dover used an initial piping elevation of 880.0 and a trigger failure water surface elevation of 910.0 while Bolivar breach conditions used an initial piping elevation of 910.0 and a trigger failure water surface elevation of 961.6.

To evaluate the four conditions listed above, it was necessary to develop the probable maximum rainfall, route and combine hydrographs to the dam, and simulate operation of the dam to determine outflows during the design event. The reservoir operations were completed using a reservoir simulation program, and the flows generated from the simulation were then placed into the Unsteady River Analysis System (HEC-RAS). The HEC-RAS model was then used to compute water surface profiles for the frequency events listed in Table 2. These profiles were then used to estimate the downstream hazards in terms of population at risk and economic damages.

Frequency Events Analyzed								
Freq. Event Years	2	3.5	64	94	210	300	700	10000
% PMF	5.5	8.3	14.7	16.2	33	36	55	100
Pool Elevation	929.0	936.1	949.0	952.0	962.0	964.0	972.3	981.5

Table 2. Frequency events analyzed for Bolivar Dam.

All the projects in the Muskingum are operated based on the downstream control which is normally located just below the project. Once the model (Ressim) determines that the storm event will exceed the downstream control, it will shut the gates to store the runoff. The gates will remain closed until there is no longer a threat of flooding or until the pool level approaches the spillway at which point the gates will be opened in an effort to keep the project from being overtopped. As soon as the storm has safely passed, the project will be operated to bring the pool back to the normal pool which is approximately 890.0. Refer to Appendix J, Hydrology and Hydraulics Analyses, for more detailed information.

7.2 Base Condition Stability Analyses

Deterministic and probabilistic seepage and slope stability analyses were completed to determine the extent of adverse conditions for foreseeable loadings at Bolivar Dam, to address uncertainty regarding project conditions, to allow economic risk analysis, and to guide the selection of a remedy that effectively reduces the risk of unsatisfactory performance for foreseeable loadings (Table 3). Analyses consisted of calculating expected factors of safety against erosion across the projected load range using finite element models calibrated to past field data and observations. Modeling was then completed using ranges of input parameters for key variables, and results were combined to yield probabilities that the expected factors of safety were less than unity for all base and proposed rehabilitation load cases. In depth presentation on major rehabilitation study modeling approaches and results for the dam's base (current) condition are contained in Paragraph 5 of Appendix H, Geotechnical Analyses - Embankment. A summary of the results of the analyses follows.

Bolivar Dam Annual Load Probabilities

Return Period (yrs)	Pool Elevation (ft)	Elevation Increment (ft)	Pr(Exceedance)	Pr(Pool)
		985.0	0.00%	
10000.0	982.0	*(Top of Dam)*		0.09%
1150.0	*(Probable Max Flood)*	973.0	0.09%	
300.0	964.0			0.31%
250.0		963.0	0.40%	
210.0	962.0			0.27%
150.0	*(Spillway)*	957.0	0.67%	
94.0	952.0			0.65%
76.0	*(~2005 Record Pool)*	950.5	1.32%	
64.0	949.0			4.24%
18.0	*(~1991 Past Record Pool)*	942.5	5.56%	
3.5	936.0			30.16%
2.8		932.5	35.71%	
2.0	929.0			64.29%
1.0		924.0	100.00%	
			$\sum =$	100.00%

Table 3. Annual load probabilities of modeled pool elevations [Pr(Pool)]. The annual loading probabilities shown represent the probabilities that the pool will be at various elevation ranges; e.g., the Pr(Pool) value for elevation 952.0 feet, as shown above, is the probability that the pool is in the range of elevations 950.5 and 957.0 feet.

The stability of the left abutment was analyzed using an expert elicitation process. Through this process experts provided Pr(u)'s and performance levels for each of the seven loading conditions in Table 3. The results of the expert elicitation for the left abutment are provided in Appendix I, Geotechnical Analyses - Left Abutment.

7.3 Summary of Analyses Results for Base Condition

Base condition seepage and slope stability analyses performed for station 5+00 located near the right abutment of the dam and station 20+00 indicate that the embankment is stable for all loading conditions for seepage and slope stability. Analyses for the adjacent reach, stations 25+00 through 29+00, which is characterized by the naturally abandoned stream channel, also indicate that there are relatively small concerns as modeled in 2D. However, potential 3D effects directly adjacent to this section could become adverse during high pool elevations. It is anticipated that problematic conditions (seepage-induced erosion) could result from seepage through day lighting gravel strata in the adjacent slopes of the old stream channel. Slope stability (2D) analyses did not indicate potential development of slope instability-related problems for this reach. The reach from stations 29+00 to 47+00 indicated unacceptable probabilities of unsatisfactory performance (Pr(u)) for through seepage at load cases above the 936 pool. Unacceptable probabilities of unsatisfactory performance from under seepage resulted from loadings greater than a 949 pool and continually deteriorated up to a 964 loading at station 43+00; however, under seepage conditions improved at the probable maximum flood pool elevation due to the projected high tail water stage. Slope stability analyses performed in this project reach indicated unacceptable conditions for loading events in excess of the 936 pool, except for the probable maximum flood case in which resisting force provided by the expected high tail water elevation resulted in an acceptable slope stability Pr(u). The combined Pr(u) was determined to be greatest (59.9 percent) in this reach for the 964 (300-year return period) pool elevation. The project reach from stations 52+50 to 64+00 is comprised of the main portion of the embankment. Generally, the main embankment's overall stability is better than the adjacent terrace sections of the dam under the current (base) condition. Slope stability analyses results indicate near zero probabilities of unsatisfactory performance for all loading conditions. However, the results do indicate that the Pr(u) due to under seepage is at a maximum of 2.4 percent at a pool elevation of 949 feet; this results from the potentially low tail water elevation during this event. The expected level of performance during the 949 feet pool at station 57+00 based on the reliability analysis is "poor".

The last reach analyzed is station 66+00, which is comprised of the left abutment. Pr(u)'s developed during an expert elicitation, using guidance provided in ETL 1110-2-547, Table B-1, indicate that the performance of the left abutment under loadings of the 929 pool, and the 936 pool would be "good to high". At the loading condition of pool 949, the performance drops to "poor" and at 952 the performance drops again to between "poor and unsatisfactory". At the 961 and 964 pools the performance drops again to between "unsatisfactory and hazardous". The performance exceeds "hazardous" at the 982 pool.

7.4 Engineering Consequences

Unsatisfactory performance was defined for this study as the initiation, continuation, and progression of erosion, with three potential failure modes: through seepage, under seepage, and slope stability. Effects of unsatisfactory performance, once it has occurred, are represented using performance level probabilities. The performance level probabilities are used in the event tree along with loading probabilities, unsatisfactory performance probabilities, and consequences to determine risk (note that details regarding specific damages associated with consequences, as well as the actual risk calculations, are contained in Appendix B of this report).

Performance levels were characterized in one of two categories: "failure" or "impacts without failure" in this study. The "failure" category consisted of catastrophic breach of dam and loss of pool, with associated consequences including: downstream inundation (above the normal amount projected for the pool); rebuilding of the dam (embankment, foundation, instrumentation, and seepage blanket); loss of storage (and associated downstream inundation) during the reconstruction period (assumed to be 2 years); and losses of transportation across the dam and recreation use during reconstruction. Parameters that were used to model the failure of Bolivar Dam are: Initial piping elevation of 910, full formation time of 0.5 hours, final bottom width of 100 ft., final bottom elevation of 905, side slopes of 0.5H:1V, and assumed occurrence at Station 50+00.

The "impacts without failure" category consisted of significant impacts resulting from unsatisfactory performance without catastrophic loss of pool. Associated consequences included: increased instrumentation monitoring, study and surveillance; repair of the dam (embankment, foundation, instrumentation, and seepage blanket); loss of storage (and associated downstream inundation) during the repair period (which ranged in duration from 6 months to 18 months depending on the pool elevation during unsatisfactory performance); potential increased downstream inundation (above the normal amount projected for the pool) due to lowering the pool (maximum release) immediately upon the occurrence of unsatisfactory performance; loss of recreation use during reconstruction; and outlet channel erosion repair due to unsatisfactory performance-related maximum release. The probabilities of each performance level occurring were determined based on observed past project performance considering the potential/probability for intervention to prevent catastrophic failure should progressive erosion develop, and by applying engineering judgment.

The hydrology and hydraulic considerations and analysis of annual load probabilities of reaching defined pools as documented in Table 3 assumes operating equipment and gates will function reliably. This assumption was carried through the 50 year life cycle of the risk-based economic model as described in Section 5.4. The consequences described above did not consider potential for unsatisfactory performance in operating equipment and gates. However, under certain loading conditions, if a failure should occur in the operating equipment or gates resulting in a gate stuck in the closed position then annual load probabilities would be expected to increase, consequently increasing potential for unsatisfactory performance and possible catastrophic loss of pool.

8.0 ALTERNATIVE DEVELOPMENT AND EVALUATION

8.1 Basis of Formulation

This chapter presents the plan formulation rationale used for this report. The Corps of Engineers five step planning process specified in ER 1105-2-100 in conjunction with Corps Major Rehabilitation guidance in EP 1130-2-500 was used to develop, evaluate, and compare the array of candidate plans that have been considered. Steps in the plan formulation process include:

1. The specific problems and opportunities to be addressed in the study were identified, and the causes of the problems were discussed and documented. Planning goals were set, objectives were established, and constraints were identified.
2. Existing and future without-project conditions (base conditions) were identified, analyzed and forecast. The base condition resources, problems, and opportunities critical to plan formulation, impact assessment, and evaluation were characterized and documented.
3. The study team formulated alternative plans that address the planning objectives. An initial set of alternatives was developed and evaluated at a preliminary level of detail.
4. Alternative project plans were evaluated and impacts of alternative plans determined as specified in the Principles and Guidelines and ER 1105-2-100.

5. Alternative plans were compared. A benefit-cost analysis was conducted to prioritize and rank rehabilitation alternatives.
6. A plan was selected for recommendation, and justification for plan selection prepared.

The plan formulation was conducted in two phases, initial screening and selection of recommended alternative.

8.2 Opportunities

There is an opportunity to significantly reduce the potential for future emergency action expenditures, loss of life, and dam failure. The opportunity to make one-time economically justified expenditures is associated with the opportunity to fulfill federal responsibilities when a problem develops to a point requiring serious corrective action. Deferral of the solutions may result in significant dam failure modes resulting in loss of life and severe economic and legal consequences. There is an opportunity to avoid these at this time by recognizing that past efforts have turned out to be piecemeal type solutions within limited funds, and that a comprehensive solution is now warranted. Refer to Section 3 for the description of problems.

8.3 Project Objectives

The establishment of Project objectives provides a framework for the development of alternative plans. As project objectives for this investigation, it is in the Federal interest to:

Contribute to National Economic Development (NED) through the reduction of failure risks and associated reliability increases related to the identified seepage problems. NED contributions include increases in the net value of national output of goods and services and can be measured in terms of monetary outputs such as reductions in Operations and Maintenance Costs, flood damages and emergency response costs.

Specific objectives to guide formulation of the rehabilitation plan for the Bolivar Dam include:

- Reduce or eliminate seepage through the embankment and abutment,
- Reduce or eliminate seepage under the embankment
- Prevent catastrophic failure of the dam due to seepage related instability.

8.4 Alternative development

Corps guidance in Appendix E of Engineering Regulation 1105-2-100 and Engineering Pamphlet 1130-2-500 requires consideration of the basic categories of alternatives in reliability studies. These categories are listed below.

1. Advance maintenance strategy. Advance maintenance strategies would consist of expenditures in excess of routine O&M that reduces the likelihood of some emergency repairs and temporary service losses, or the rate of service degradation. The existing O&M budget could be increased to provide funds for advanced maintenance towards the problem or for scheduled repairs. This would essentially entail attempting to correct the problem over time as the potentially increased O&M budget would permit.

2. Scheduled repair strategy. Assess the components of the feature in terms of the service disruption probabilities and consequences to the reliability of the structure. Based on this assessment, stockpile replacement parts and make other preparations on this assessment to reduce the time of expected project service disruption.

3. Scheduled rehabilitation strategy. The scheduled rehabilitation strategy requires that the optimum rehabilitation timing be identified based on service disruption rates, service degradation and their economic cost.

4. Immediate rehabilitation. Rehabilitation alternatives that seek to complete correction of the problems as soon as possible.

8.5 Initial Alternative Screening

During initial phases of project formulation, several alternatives were considered to address the stated purpose and need. As indicated in the engineering studies, two separable component features of the Bolivar Dam were determined to be in need of rehabilitation. These components are the main embankment and left abutment. As separable components they will be justified independently of each other. Therefore, alternatives to address planning objectives were developed for each component. These alternatives were evaluated based on their ability to meet project objectives considering engineering, economic and environmental feasibility. From this initial screening, four alternatives were retained for detailed consideration. A detailed description and evaluation of each alternative is provided below followed by a summary of initial screening rationale presented in Table +.

8.5.1 Advanced Maintenance Strategy

Advanced maintenance and scheduled repair strategies entail increasing the existing O&M budget to seek funds for activities which would attempt to correct the problem over time. Alternatives in this category would be implemented only if an increased O&M budget would permit. Due to the nature and scope of the problems discussed in paragraph 3 as well as the performance of Bolivar Dam during high water events, scheduled repairs would not effectively address seepage problems or measurably reduce the risk of dam failure and associated pool release during flood events. This dam design predates modern seepage stability analyses, and requires specialized construction equipment and techniques which are not appropriate for incremental construction. The risk of a dam failure under piecemeal solutions that rely upon questionable annual appropriations, even under increased budget scenarios, would not be measurably decreased. Therefore, Advanced Maintenance and Scheduled Repair alternative measures are screened from further consideration.

8.5.2 Scheduled Rehabilitation Alternatives

The scheduled rehabilitation alternative is the deferral of all rehabilitation work into the future. The scheduled rehabilitation and the immediate rehabilitation alternatives consist of the same repair actions, except that the timing of the implementation varies. The optimum time for construction of the project depends on the reliability of the project, how reliability changes over time, and the consequences of unsatisfactory performance. For the timing analysis a ten year delay in rehabilitation effort, which is the required "scheduled" rehabilitation alternative, was evaluated with the economics compared to those of immediate rehabilitation. If the ten year delay was more economic, then the timing would have been optimized through further analysis.

Economic analysis of scheduled rehabilitation for the Bolivar Dam indicated the scheduled rehabilitation was not economical when compared to immediate rehabilitation alternatives. Moreover, scheduled rehabilitation measures would prolong the existing risks of dam failure. This alternative was therefore screened from further consideration. The detailed result of scheduled rehabilitation analysis is documented in Appendix B, Risk and Reliability Analysis. The results indicate that the immediate rehabilitation alternative is economically preferred compared to the scheduled rehabilitation. Scheduled rehabilitation alternatives were therefore screened from further consideration.

8.5.3 Immediate Rehabilitation Alternatives

Immediate rehabilitation will be accomplished as soon as is possible, given the constraints of budgeting and funding. Immediate rehabilitation alternatives for each separable component, the main embankment, and left abutment are considered below. Additional technical detail for each immediate rehabilitation alternative can be found in Appendices H through K.

8.5.3.1 Main Embankment Alternatives Considered

Full-Depth, Full-Length Seepage Barrier

Construction of a seepage cutoff barrier which extends the full length of the dam and through the entire foundation would reduce embankment seepage and associated stability-related risks to tolerable levels. However, this alternative is not necessary considering that projected stability does not require such a barrier in all project reaches, and that tolerable risk reduction can be achieved in reaches requiring remedy through the implementation of an optimized partial-length and partial-depth barrier in conjunction with other remedy components, as discussed below. Extending a seepage barrier entirely through the foundation and keying it into bedrock would be much more costly (Table 4) than the optimized seepage barrier alternative proposed below, and could also adversely impact regional groundwater relative to the proposed barrier. On these bases, the full-depth and full-length seepage barrier alternative was screened from further consideration.

Partial-Depth, Partial-Length Seepage Barrier- Upstream Toe Alignment

The partial depth, partial-length seepage barrier would be placed between stations 20+00 and 64+00. The alignment (Figure 11) at the upstream toe of the dam embankment would consist of a partial-depth concrete seepage barrier which would be installed at a constant depth of 135 feet below existing ground surface. To address through seepage, an impervious blanket ranging from 5 to 8 feet in thickness would be placed from the upstream toe of the dam to its crest and revegetated with grasses. The partial-depth, partial length alternative includes augmenting the existing downstream seepage blanket. Screening decision: this alternative adequately met project objectives and was therefore retained.

Partial-Depth, Partial-Length Seepage Barrier – Crest/Centerline Alignment

Similar to the upstream toe alignment, the partial depth, partial-length seepage barrier would also be placed between stations 20+00 and 64+00 and would provide for the same increases in reliability. The crest alignment would be placed through the centerline of the dam to address under seepage and through seepage which eliminates the need for an impervious blanket on the upstream face of the embankment (Figure). The centerline seepage barrier would require the removal and replacement of the existing parapet wall which runs along the crest of the dam and would require placement of a significant amount of material (or removal of the dam top) to provide a suitable construction platform width. The crest/centerline barrier would also impede traffic across the crest roadway during construction. The centerline alignment would require seepage barrier construction to a greater depth resulting in more risk and costs over the increased square footage of wall. For these reasons, the construction costs would be significantly higher than the upstream alignment. Because the crest alignment would have higher construction costs, more traffic impacts and would produce the same increases in reliability as the upstream alignment, this alternative was screened from further consideration.

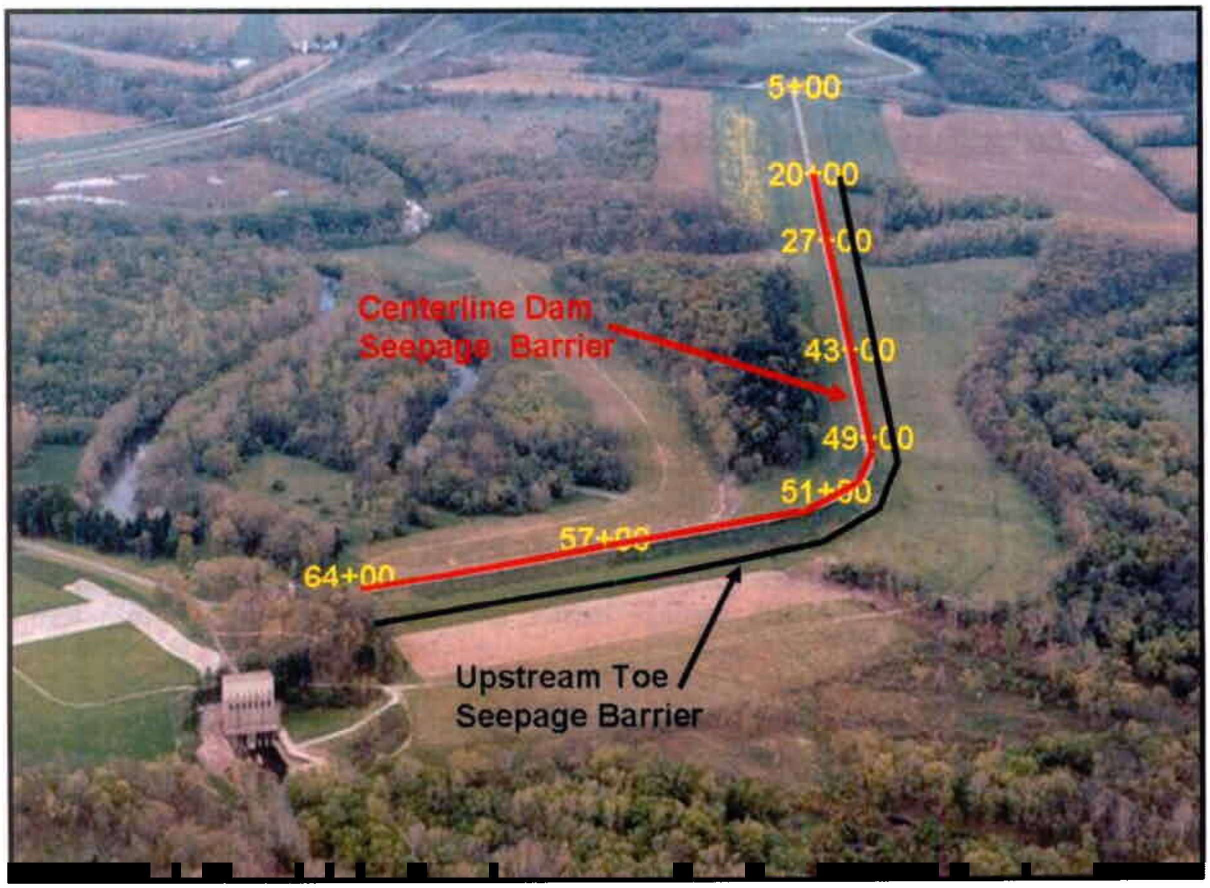

Figure 11. The red line indicates the alignment of the Centerline seepage barrier subsurface cutoff wall, and the black line indicates the alignment of the upstream seepage barrier. The photograph view is towards the northeast.

8.5.3.2 Left Abutment Alternatives Considered

Three methods were evaluated for eliminating the uncontrolled seepage out of the cut rock slope around the outlet works which has been observed at pools greater than approximate elevation 940. The three alternatives considered are: 1) Installation of a grout curtain from the embankment/abutment contact along the centerline of the dam to the outlet tunnel alignment and then upstream to the outlet channel area in conjunction with a radial grouting program from within the outlet tunnels ; 2) Seepage cutoff wall to 60 ft. depth also in conjunction with radial grouting of the outlet tunnels; and 3) Impervious blanket material on the upstream face of the abutment and spillway plus radial grouting of the outlet tunnels. The alternatives were evaluated through an expert elicitation process. The impervious blanket alternative was the least costly alternative analyzed (Table 4); however evaluation through the expert elicitation process this alternative did not provide satisfactory performance for most loading conditions. The grout curtain provided significant improvement for lower pool elevations; however the cement/bentonite cutoff wall in conjuction with radial grouting of the outlet tunnels as the only alternative that provided probabilities of unsatisfactory performance that represent adequate performance at all loading conditions. The three foot wide seepage barrier will begin at Station 64+00, tying into the embankment seepage barrier, and will follow the existing access road alignment to a point opposite the stilling basin and then turn in the upstream direction to just above the outlet channel (Figure 12). Radial grouting will be performed along three sections of each outlet tunnel to ensure adequate seepage cutoff along the tunnel alignments.

8.5.4 No Action

The No Action Alternative is synonymous with the base condition of the project. It is defined as the current condition of the project components and their expected outcome if status quo practices of operation, maintenance and repair are continued. This condition is also referred to as the baseline, without project, existing condition, "fix-as-fails," alternative. It is the condition to which all other evaluated alternatives are compared in order to determine their effectiveness as an investment in the project.

Under the No Action Alternative, we assume the minimal capital investment alternative in terms of doing preventative maintenance on the dam components. Problematic seepage at the dam would continue and is expected to worsen over time leading to increased risks of failure. If a project component fails under the base condition, it is assumed that emergency repairs will be made to the feature. As required by ER 1105-2-100 and the National Environmental Policy Act this alternative will be carried forward and will be included among the final array or alternatives for consideration and comparison.

8.5.5 Nonstructural Measures

8.5.5.1 Removal of Dam

The annualized costs of removal of approximately $1 million plus the subsequent losses in annual benefits of approximately $8 million dollars per year greatly exceed the annual cost savings which would be realized. Moreover the dam can be rehabilitated for $70 million dollars a payback period of less than 10 years. The dam removal alternative was therefore screened from further consideration.

8.5.5.2 Modified Operational Procedures and Pool Restrictions

Attempting to operate the project in the future as a perpetually dry or limited capacity reservoir would decrease stability-related risks but would certainly eliminate or significantly decrease annual flood control benefits realized downstream of the dam. Moreover, operation at a perpetually dry or limited capacity would not eliminate the potential for dam failure during high pool levels caused by flood events. This alternative was screened from further consideration.

8.5.5.3 Expanded Seepage Monitoring

Seepage monitoring during pool retention should be continued regardless of what additional design changes would be implemented in the future. This is due to the history of observed seepage occurrences that have been documented over the lifetime of the project and the soils which the project is built on. However, expansion of seepage monitoring would not address the causative problems or reduce the related risks of dam failure; risk reduction could only occur through measures aimed at addressing seepage problems. Because this measure does not meet project objectives it was screened from further consideration.

Initial Screening Summary

Name	Cost*	Environmental consideration	Screening Decision/Rationale
Advanced Maintenance Alternatives	N/A. Would be dependent on increases in O&M budget	Advanced Maintenance would entail smaller, piecemeal solutions to address seepage problems. These may result in recurring impact to resources.	Because of the nature and scope of the problems and performance of Bolivar dam, scheduled repairs would not effectively address seepage problem or measurably reduce the risk of dam failure. Screening Decision: Eliminated.
Scheduled Rehabilitation	Approximately 40% less Net Benefits than Immediate Rehabilitation	Same as immediate Rehabilitation Alternatives.	Risk based analysis indicated scheduled rehabilitation was not economical when compared to immediate rehabilitation alternatives. Moreover, scheduled rehabilitation measures would prolong the existing risks of dam failure. Screening Decision: Eliminated
Main Embankment - Full-Depth, Full-Length Seepage Barrier	$145,388,000	Impact to traffic patterns due to road closure. Potential for adverse effects on local roadways due to increased construction traffic due to substantial amounts of spoil. Greater potential for cultural resource impacts than partial alternatives.	The alternative would meet project objectives. However, the alternative is substantially more expensive than other alternatives. Screening Decision: Eliminated.
Main Embankment - Partial-Depth, Partial-Length Seepage Barrier – Upstream Alignment	$70,541,000	Downstream granular seepage blanket would be placed in an emergent wetland. Potential for cultural resource impacts.	The alternative would meet project objectives. Screening Decision: Retained.
Main Embankment - Partial-Depth, Partial-Length Seepage Barrier – Crest/Centerline Alignment	$95,371,000	Downstream granular seepage blanket would be placed in an emergent wetland. Impacts to traffic patterns due to road closure during construction period. Potential for cultural resource impacts.	This alternative was significantly more costly than the upstream toe seepage barrier alternative and met project objectives equally to the upstream alignment. The crest/centerline barrier would also impede traffic across the crest roadway during construction. Screening decision: Eliminated.

Left Abutment - Grout Curtain & Radial Grouting of Outlets	$1,500,000	Impacts to traffic patterns due to construction. Potential for cultural resource impacts.	This alternative, though less costly than cutoff would not provide adequate seepage cutoff at all loading conditions. As such this alternative would not meet planning objectives. Screening decision: Eliminated
Left Abutment - Seepage Cutoff Wall & Radial Grouting of Outlets	$3,453,000	Impacts to traffic patterns due to construction. Potential for cultural resource impacts.	This alternative adequately met project objectives. Screening Decision: Retained.
Left Abutment - Impervious blanket	$1,050,000	May require additional tree clearing and impacts to roads from hauling operations during construction.	This alternative, though less costly than cutoff would not provide adequate seepage cutoff at all loading conditions. As such this alternative would not meet planning objectives. Screening decision: Eliminated
No Action Alternative	N/A	Dam failure would result in significant environmental effects including but not limited to loss of life, loss of property, sedimentation and erosion, impacts to riparian forests, cultural resources, T&E species.	Although this alternative would not meet project objectives, it is retained for comparison to action alternatives as required by Major Rehabilitation guidance and the National Environmental Policy Act. Screening Decision: Retained
Dam Removal	$14,410,000	Elimination of a National Register eligible structure. Increased sedimentation during removal. Potential for increased frequency of downstream flooding	The annualized costs of removal plus the subsequent losses in annual benefits greatly exceed the annual cost savings which would be realized. Screening decision: Eliminated
Pool Restrictions	N/A	Potential for increased frequency of downstream flooding	Flood control benefits would be eliminated or minimal. Moreover, this measure would not eliminate the potential for dam failure during high pool levels caused by flood events. Screening decision: Eliminated
Expanded Seepage Monitoring	N/A	No Effects	Expansion of seepage monitoring would not address the causative problems or reduce the related risks of dam failure. Screening decision: Eliminated

*Screening Level Costs at the FY06 Price level.

Table 4. Summary of initial screening alternatives for Bolivar Dam.

8.6 Final Screening and Selection of Recommended Alternative

For the final screening, the alternatives which were not eliminated were analyzed both independently and in combination to determine the most economic investment. As the environmental effects of final alternatives are considered minor and insignificant, all alternatives were considered nearly equal in terms of environmental acceptability. As such economic considerations were used as the main consideration in the final screening. Alternatives that were retained for further consideration in the final screening are listed below:

4. Partial Depth/Length Concrete Seepage Barrier (Main Embankment)
5. Seepage Cutoff Wall (Left abutment)
6. Combination (Main Embankment + Left Abutment)
4. No Federal Action or Base condition

As discussed in Section 5.0, Economic Considerations and in much greater detail in Appendix B, a risk and reliability analysis using a Monte Carlo type simulation was used to determine expected consequences of the base condition and alternatives for each separable component. The core logic of the model is the possible sequences of events shown on the event trees developed specifically to represent the baseline conditions as well as the with project conditions for various pool levels. The model keeps a running tabulation of the consequences for each of the fifty years in the project life and for each of the thousands of life-cycle simulation runs. Following completion of all iterations, the disbenefits and repair costs by year are converted to their present value equivalents, summed, and converted to an average annual equivalent value, which is then used in the benefit calculation. The model was designed to perform these operations for each separable component and for the combination of these alternatives. The table below summarizes the average annual project benefits as determined by the life cycle model.

AVERAGE ANNUAL BENEFITS			
Individual Component or Combination	**Base Condition Consequences**	**With Project Economic Consequences**	**Benefits**
Main Embankment (Partial Length/Depth Cutoff)	$12,384,000	$2,000	$12,382,000
Left Abutment (Cutoff + Radial Tunnel Grouting)	$373,000	$0	$373,000
Combination Main Embankment + Left Abutment	**$12,701,000**	$2,000	**$12,699,000**

Table 5. Average annual benefits by life cycle model.

The economics of the alternatives were determined by comparing the benefits they provide with the costs of construction and maintenance. Specifically, the average annual costs are subtracted from the average annual equivalent benefits with the difference referred to as the net benefits. If the net benefits were positive then the alternative was cost-effective; if negative then it was not cost effective. All three alternatives are cost effective as shown in the table below.

NET BENEFITS – FY06 Price Level (screening level)				
Individual Component or Combination	**Average Annual Benefits**	**Average Annual Costs**	**Net Benefits**	**BCR**
Main Embankment (Partial Length/Depth Cutoff)	$12,382,000	$4,521,000	$5,238,000	2.7
Left Abutment (Cutoff + Grouting)	$373,000	$221,000	$79,000	1.7
Main Embankment + Left Abutment	**$12,699,000**	**$4,378,000**	**$5,424,000**	**2.9**

Table 6. Net benefits of alternatives for Bolivar Dam.

The alternative which maximizes Net Benefits, or the National Economic Development (NED) plan, is the combination of Main Embankment Partial Length/Depth Cutoff and Left Abutment Cutoff Wall. This is considered the Recommended Plan. The average annual benefits for the recommended plan are $12.7 million. The data in the table above is based on screening level cost estimates. The average annual costs, using screening level costs, are approximately $4.4 million with a Benefit to Cost Ratio (BCR) of 2.9.

A more detailed evaluation of costs, referred to as baseline cost level estimates was conducted for the final array of alternatives. An explanation for the difference in project costs from screening level to baseline level is included in Section 12. The table below summarizes Economic considerations of the final array of alternatives using baseline level cost estimates.

Summary of Economic Considerations – FY08 Price Level (baseline level)				
Individual Component or Combination	**Average Annual Benefits**	**Average Annual Costs**	**Net Benefits**	**BCR**
Main Embankment (Partial Length/Depth Cutoff)	$12,382,000	$7,067,000	$5,315,000	1.8
Left Abutment (Cutoff + Grouting)	$373,000	$224,000	$150,000	1.7
Main Embankment + Left Abutment	**$12,699,000**	**$7,218,000**	**$5,481,000**	**1.8**

Table 7. Net benefits of alternatives for Bolivar Dam.

The economic considerations using baseline level cost estimates support the conclusions made with screening level costs. The alternative which maximizes Net Benefits, or the National Economic Development (NED) plan, remains the combination of Main Embankment Partial Length/Depth Cutoff and Left Abutment Cutoff Wall. The average annual cost of the recommended alternative, using baseline level costs, is approximately $7.2 million and has a BCR of 1.8.

9.0 RECOMMENDED PLAN

Major construction features of the recommended plan (Figure 12) include a partial-depth and partial-length concrete seepage barrier on the upstream toe of the dam, a seepage barrier cutoff wall in the left abutment of the dam, augmentation of the existing downstream seepage blanket, rehabilitation of the operating machinery and gates, the maintenance and/or rehabilitation of the existing relief well system as necessary to maintain adequate efficiency, instrumentation-related improvements (for existing piezometers and relief wells), and the installation of additional instrumentation (piezometers, surface displacement monuments, and inclinometers) to provide adequate post-remediation monitoring capability. More detailed information on the recommended plan is presented below.

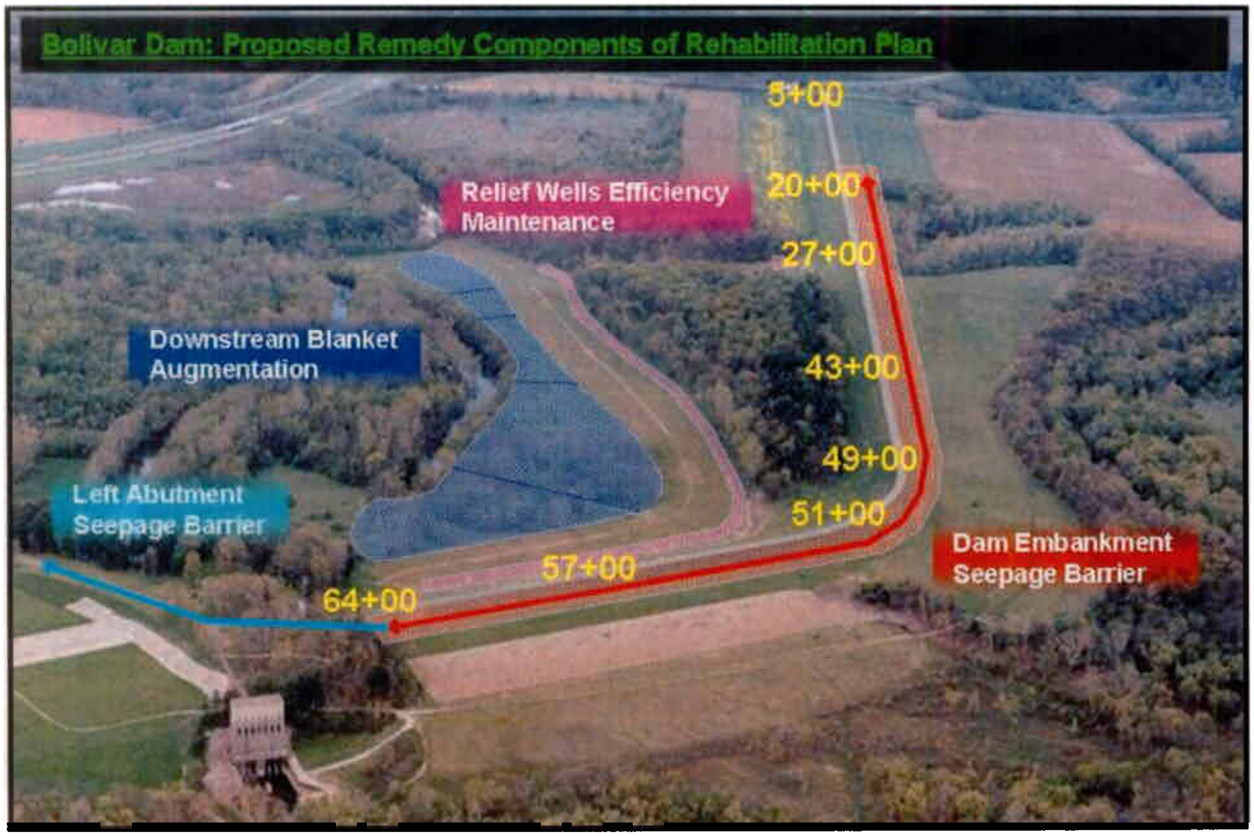

Figure 12. Layouts of the proposed downstream seepage blanket augmentation (blue region), left abutment seepage barrier (turquoise line), relief wells efficiency maintenance (pink regions), and the seepage barrier construction (red line and region) rehabilitation plan components (see text for discussion) for Bolivar Dam. The heavy red line indicates the alignment of the seepage barrier subsurface cutoff wall, and the adjacent red region indicates seepage barrier impervious fill placement. The recommended rehabilitation plan also includes instrumentation-related improvements and additions. The photograph view is towards the northeast.

9.1 Partial-Depth and Partial-Length Seepage Barrier

The proposed seepage barrier (Figures 12 and 13) will be located between stations 20+00 and 64+00, and will consist of relatively impervious material (ranging from 5 to 8 feet in thickness, depending on placement surface slope) being placed from the upstream toe of the dam to its crest. The impervious material will be obtained from a commercial source. Near the upstream dam toe, a concrete panel cutoff wall will be installed to a constant 135 feet depth below existing ground surface. Concrete panel construction is desirable relative to sheet piling (due to large gravels, required wall depth, and likely greater deterioration over time of sheet piling) and bentonite slurry trenching (due to open work gravels and high gradients which will exist across the wall). The lowest elevation along the upstream dam toe where barrier-related construction will occur is 941 feet; statistically, this elevation should be dry throughout remedy construction, as it is equivalent to a pool elevation with a return period of 10 years. Spoil material from the cutoff wall construction will be placed on government property in an abandoned quarry west of the right abutment as shown on Exhibit C-1. Prior to construction of the proposed seepage barrier, additional drilling will be conducted along and at the extents of its alignment in order to define with higher resolution any gravel strata and foundation thickness variances, and applicable construction methods and approaches will be researched and evaluated, and a test-phase of construction (with performance testing of built conditions) will be performed prior to full-scale construction along the entire cutoff alignment.

Refer to Exhibits C-3 and C-5 for additional plan and typical section views of the proposed seepage barrier.

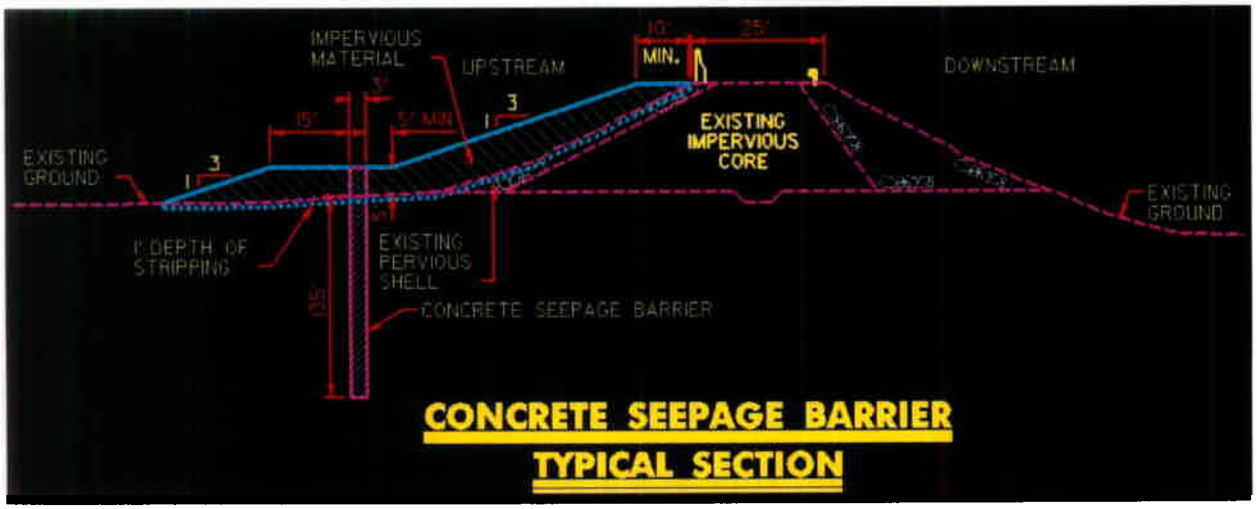

Figure 13. Typical section view of the proposed embankment seepage barrier.

9.2 Downstream Seepage Blanket Augmentation

The proposed seepage blanket augmentation (Figure 12) will be located beyond the existing downstream seepage blanket between approximate stations 24+00 and 64+00. Analyses indicate that extending the existing blanket a minimum of 200 feet downstream in the range of stations 43+00 to 57+00 would resolve base condition stability concerns related to under seepage; note that these results are dependent upon continued positive (foundation pressure relief) contributions provided by the existing relief wells. While the partial-depth and partial-length seepage barrier remedy component will significantly reduce seepage quantities and gradients exiting through terrace gravel strata, deep foundation flow path seepage will still exit downstream of the existing seepage blanket, resulting in downstream under seepage concerns for certain pools with accompanying low tail water elevation. The proposed plan includes extending the blanket augmentation across a wider station range than analyses indicate is minimally necessary to prevent seepage-induced erosion initiation. Expanding the blanket augmentation in such fashion is based on the desire to blanket regions where exiting under seepage (albeit with very low predicted exit gradients) is predicted to occur. This will provide added resilience to the remediation at a relatively low additional cost.

The blanket's top elevation will slope from elevation 904 feet where it will adjoin the current blanket to a top elevation of 902 feet at its downstream crown. The downstream extent of the blanket will terminate at a distance of at least 30 feet from the old Sandy Creek stream channel in order to minimize potential adverse environmental-related affects. Expansion of the downstream seepage blanket will also require extension of existing relief well outlet pipes, and construction of two concrete junction boxes to combine the flow from multiple outlets. For this report it is assumed the blanket material will consist of bank run sand from a commercial source, however a potential onsite borrow area, located west of the right abutment as shown on Exhibit C-1, will be investigated during the DDR phase for a portion of the needed material. Refer to Exhibits C-4 and C-5 for plan and typical section views of the seepage blanket.

9.3 Relief Wells Efficiency Maintenance

Analyses conducted demonstrate that relief wells provide benefits towards alleviating through seepage, under seepage, and slope stability failure mode concerns. Therefore, an important component of the recommended rehabilitation plan for Bolivar Dam is the adequate maintenance of existing relief wells efficiency. There is the likely potential for well performance decline over time at the project, and currently there is no implemented inspection, monitoring, and maintenance program for the wells. This remedy component will be completed through an initial characterization of the well system capability (in terms of layout and efficiency), which will be accomplished through detailed depth and spacing design calculations, and a condition assessment study involving down-hole video, groundwater analyses, and hydraulic testing. Based on this characterization work, an adequate inspection, monitoring, and preventative maintenance and/or rehabilitation plan for the wells will be developed and implemented. This plan will likely be revised and optimized after its implementation, as will be determined by periodic analyses of acquired performance-related data as part of the plan. It is important to note that if viewed from a long-term cost standpoint, the total cost of an appropriately designed and implemented plan, as proposed, would be less than the cost of measures such as periodic extensive rehabilitation to restore efficiency or the replacement of wells if efficiency deteriorates to the point where it cannot be restored. It is also important to note that the long-term costs of maintaining well efficiency as is proposed would be less than the difference in costs of installing a full-depth seepage barrier between stations 20+00 and 64+00 versus installing the proposed partial-depth and partial-length seepage barrier (as detailed above). Costs for maintaining the relief wells are typically $40,000 to $50,000 per year with a worst-case scenario of $350,000 per year for full maintenance. The table below summarizes the difference in size/costs between the full-depth and partial-depth seepage barriers using the most recent square foot costs. Assuming a 50-year analysis period, the difference in the average annual costs per year between the full-depth and partial depth seepage barriers is $900,432. Therefore, the average yearly costs for the partial-depth barrier and relief well maintenance are substantially lower than construction of the full-depth barrier. Without benefits provided by relief wells and the above-discussed downstream seepage blanket augmentation, a full-depth seepage barrier would be required between stations 20+00 and 64+00 to obtain adequate seepage and slope stability FS and Pr(u) values.

Description	Size (SF)	Cost/SF	Cost	Cost/Year
Full-Depth Seepage Barrier	1,140,000	$86.58	$98,701,200	$1,974,024
Partial-Depth Seepage Barrier	620,000	$86.58	$53,679,600	$1,073,592
Difference			$45,021,600	$900,432

**Does not include contingencies.*

Table 8. Full-Depth vs. Partial-Depth Barrier Comparison

9.4 Instrumentation Improvements

The recommended rehabilitation plan for Bolivar Dam includes instrumentation-related improvements (for existing piezometers and relief wells), and the installation of additional instrumentation (piezometers, surface displacement monuments, and inclinometers) to provide adequate post-remediation monitoring capability. Existing downstream piezometers and relief wells cannot be monitored during low-frequency events (when pool elevation is equal to or greater than 949 feet) because they are submerged by tail water. Artesian flow above piezometer riser tops has also been experienced during past events, and has disallowed accurate pore pressure data from being obtained. Relief well flows have not been able to be measured with enough frequency in the past to allow conclusions regarding well system (as well as dam foundation) performance over time to be reached. To address these issues, existing downstream piezometers will be upgraded to an automated (e.g. pressure-gauge) system which will allow measurements to be made during times of artesian flow or submergence by tail water. Existing relief wells will be upgraded with a (e.g. inline flow meter) system so that measurements can be made during periods of downstream submergence by tail water and continuously during all retained pool events. Exact details regarding the desired design and implementation of these data acquisition systems will be determined prior to their implementation [in the Design Document and Reporting (DDR) phase].

This remedy component also involves the installation of additional piezometers to improve the current monitoring network. New piezometers (e.g. nested depth sets) will be installed at various locations through and beyond the proposed downstream seepage blanket augmentation to monitor excess head and gradients. New piezometers will be installed immediately upstream, downstream, adjacent to, and in between certain relief wells to provide important data regarding relief well performance and pressure relief achieved as a function of distance away from relief wells. New piezometers will be installed along transects (east and west) across and orthogonal to the existing downstream rock toe to verify that low gradients which are predicted by analyses continue to be realized in this region of the project. New piezometers will also be installed along linear transects adjacent (east and west) and orthogonal to the proposed seepage barrier in order to measure head dissipation achieved by and gradients across the barrier. Note that an automated system will be required for these upstream piezometers as well since their riser tops will be submerged during low-frequency pools. Surface displacement monuments and inclinometers will be installed along and through the proposed seepage barrier. These instruments will allow important conclusions to be made over time regarding the integrity (e.g. possible settlement or deflection) of the seepage barrier cutoff wall. Exact details regarding the desired design, layout, and implementation of these instruments will be determined prior to their implementation (in the DDR phase).

9.5 Left Abutment Seepage Barrier

The three foot wide abutment cutoff wall will tie into the embankment seepage barrier at station 64+00, cross over the dual outlet tunnels, intersect the existing Bolivar Dam access road, and then turn west to a point opposite the stilling basin (Figure 12). The cutoff wall will be installed at a depth of 60 feet, which would effectively provide a barrier at the seepage zone located at elevation 935. Material resulting from excavation of the cutoff wall will be spoiled in the onsite spoil area shown on Exhibit C-1. In addition to the cutoff wall barrier, radial grouting will be performed from inside the outlet tunnels. Refer to Exhibits C-1 and C-6 for plan and typical section views of the abutment cutoff wall.

9.6 Operating Equipment and Gates

The recommended rehabilitation plan for the operating equipment will improve the overall reliability of the project thereby decreasing the probability of failure. Appendix K shows the computed change in reliability for the components in the current condition and in twenty years without any rehabilitation. Also shown is the change in reliability for the components in a rehabilitated condition now and in fifty years.

For the operating gates specifically, it is recommended to replace the six original riveted structural steel operating gates with new welded structural steel operating gates. Replacement of the gates would significantly reduce the potential of a gate(s) failure in the closed position leading to an increased lake elevation and potential dam failure. It is also recommended to rehabilitate the existing cast iron liners and other embedded metals associated with the six operating gates.

9.7 Interim Risk Reduction Measures

An Interim Risk Reduction Measures Plan (IRRMP) has been developed for the project and certain measures discussed in the plan have already been fully implemented, such as the updating of the dam safety emergency action plan, the establishment of a District and public communication plan, the completion of a functional emergency flood exercise, the surveying of existing surface displacement monuments, establishment of an interim surveillance plan, and the establishment of a target interim (until rehabilitation is completed) operating pool at elevation 949 feet. Certain measures, such as the clearing of some downstream areas where excessive vegetation exists, the installation of additional piezometers in some of the areas where they are needed, and the identification of commercial aggregate suppliers (for possible flood-fighting) have already been partially completed. Efforts towards the completion of the above measures which have been partially completed are in progress, as are the designs and implementations of additional measures, including the construction of a downstream access road (to improve downstream access for possible flood-fighting), the stockpiling of granular materials (to improve flood-fighting capability), and the updating of downstream inundation maps. It is likely these interim measures would be implemented prior to completion of the above-recommended rehabilitation plan; however, if certain measures have not been implemented at the time the rehabilitation plan is being fully implemented, then they all (except for the interim surveillance plan) should be considered as necessary rehabilitation plan components.

As described in Section 1.4 and 6.0, the measure within the IRRMP is currently being evaluated pursuant to NEPA. An EA is being prepared for the downstream clearing activities. The Major Rehabilitation Report/EA assumes the existing condition to be that with the downstream tree clearing has occurred. If that would not be the case, additional evaluation and documentation pursuant to NEPA would be required.

9.8 Construction of Recommended Plan

Construction of the recommended plan is expected to be performed over a 48 month contract period. The current construction schedule assumes the construction office work will begin January 2011 and be completed prior to the Major Rehab construction; Major Rehab construction is currently scheduled to begin August 2011 and be completed in December 2014. Refer to Appendix G, Fully Funded Project Costs & Schedule for the complete project schedule and projected fully funded costs. Exhibit C-2 shows the location of the proposed Contractor Work Limits (CWL) and major features of construction. All construction will take place on government owned land. Proposed borrow and spoil areas are located west of the right abutment for use during construction, and adequate areas exist within the CWL for contractor laydown and operation areas. Haul roads will be required from the upstream seepage barrier area to the spoil area, and from the borrow area to the downstream seepage blanket as shown on Exhibit C-2.

Access to the dam from both the north and south is available over existing local roads to Interstate 77. Bolivar Dam road, which follows the crest of the dam, will be closed for a majority of the construction period. Closure of the road, which has been the normal procedure on previous construction, will not result in any major detours for local traffic, and will prevent public vehicular access within the CWL. The contractor will be required to maintain access to the existing project operations building and new construction office located near the left abutment. The construction office is planned as a permanent dual use facility and will be designed for operations use as a new project office once the major rehabilitation of Bolivar dam is complete.

The construction method for the seepage barrier was assumed to be in approximately 10 ft. long panels excavated by a Bauer Hydromill. Bentonite slurry would be pumped in to maintain the trench as the excavated cuttings are pumped to the surface. The excavated material would be pumped out to a desander where cuttings are removed and slurry is returned to the trench to be reused. Cuttings would then be hauled to the spoil area. Final concrete placement in the panels would be by the tremie method with displaced slurry again pumped for reuse. Panels would be overlapped approximately 1 ft. on each side to ensure a watertight barrier. The abutment cutoff wall construction method would employ a long stick hydraulic excavator with rock breaking attachment. Additional methods will also be investigated during the next design phase of the project.

9.9 Operation and Maintenance

Upon completion of construction the above features would be turned over to operation's personnel to operate and maintain. Additional O&M costs are not anticipated with the recommended plan. Operation and maintenance (O&M) costs are the annual cost required to operate and maintain the project. The constructed seepage barrier and abutment cutoff wall would not require O&M. Maintenance of the relief wells, machinery, and gates will be substantially reduced for a number of years as a result of this rehabilitation, and will offset minor O&M of the additional instrumentation. Historic maintenance costs recorded since 1971 are listed in Table .

10.0 MAJOR REHABILITATION CLASSIFICATION

The proposed project meets the requirements of the Major Rehabilitation funding for the Reliability Improvement classification. No benefits are claimed for the Efficiency Improvement category. The project significantly extends the physical life of Bolivar Dam and is justified by a benefit-cost analysis. The recommended plan total project cost to address the seepage problem is $142,662,000. Construction is to take place over three construction seasons. Net economic benefits of the recommended alternative using baseline or (MCACES) level cost estimates have been estimated at approximately $5.4M annually and the benefit-cost ratio is 1.8 to 1. The table below summarizes Economic considerations of the final array of alternatives using MCACES level cost estimates.

Summary of Economic Considerations – FY08 Price Level (baseline level)				
Individual Component or Combination	Average Annual Benefits	Average Annual Costs	Net Benefits	BCR
Main Embankment (Partial Length/Depth Cutoff)	$12,382,000	$7,067,000	$5,315,000	1.8
Left Abutment (Cutoff + Grouting)	$373,000	$224,000	$150,000	1.7
Main Embankment + Left Abutment	$12,699,000	$7,218,000	$5,481,000	1.8

Table 9. Summary of Economic Considerations FY08 Price level (baseline level) Cost Estimate

The proposed project improvements will reduce the chance of unsatisfactory performance over time and improve reliability resulting in decreased operation and maintenance costs. The improvements will allow operation of Bolivar Dam as originally designed and eliminate the requirement for an interim operating pool.

11.0 OTHER CONSIDERATIONS

A major reason for improving the safety of Bolivar Dam is to avoid the loss of life that would likely occur from a dam failure. A loss of life analysis was performed for the Bolivar Dam using US. Department of Interior, Bureau of Reclamation (BOR) guidance. This analysis is provided in Appendix B. Using previous studies, inundation maps and the downstream flow profiles, population at risk (PAR) is estimated for various flood zones in downstream reaches. PAR, defined as those persons that would be exposed to injury by floodwater if they took no measures to evacuate, includes permanent and transient population. The effectiveness of warnings and evacuation procedures are considered when estimating the loss of life. Key factors in these analyses are the water surface profiles and travel times located in Appendix J.

The analysis indicated there was significant loss of life associated with dam failure. A table summarizing the results is included below.

Flood Condition	Distance From Dam (Miles)	Average Arrival *Time (Hours)	Incremental Persons-at-Risk	Fatality Rate w/Fail	Loss of Life with Failure	Fatality Rate w/o Fail	Loss of Life w/o Failure
60% PMF							
Reach 1, Bolivar Dam - Dover Dam	0.4-9.7	3.5	432	0.03	12.96	0.0003	0
Reach 2, Dover Dam - Gnadenhutten	9.8-35.5	10.5	3,559	0.03	106.77	0.0002	1
Total			3,991		120		1
100% PMF							
Reach 1Bolivar Dam - Dover Dam	0.4-9.7	3	54	0.03	1.62	0.0003	0
Reach 2, Dover Dam - Gnadenhutten	9.8-35.5	9	4,088	0.03	122.64	0.0002	1
Total			**4,142**		**124**		**1**

Table 10. Summary of Loss of Life Considerations.

12.0 PROJECT COST ESTIMATE

Total project cost prior to fully-funding is $123,976,000 at FY08 price level. The total fully-funded project cost is $142,662,000. The table below summarizes these costs broken out by feature account.

Bolivar Recommended Plan Total Project Cost

Feature Account	Description	Non-Fully Funded	Fully Funded
01	Lands & Damages	$124,000	$129,000
04	Dams	$98,768,000	$112,787,000
18	Cultural Resource Preservation	$875,000	$958,000
19	Building, Grounds & Utilities	$380,000	$416,000
22	Feasibility Studies	$1,782,000	$1,782,000
30	Engineering and Design	$14,545,000	$17,161,000
31	Supervision & Administration	$7,502,000	$9,428,000
	Total	**$123,976,000**	**$142,662,000**

Table 11. Total project cost estimate for the recommended plan at FY08 Price Level.

DESCRIPTION	QTY	UOM	Contract Cost	Contingency	Project Cost
01 Lands and Damages	**1**	**JOB**	**90,000**	**34,000**	**124,000**
Pre-Authorization Planning	1	JOB	90,000	34,000	124,000
04 Dams	**1**	**JOB**	**79,015,000**	**19,754,000**	**98,768,000**
1 Mobilization/Demobilization	1	JOB	800,000	200,000	1,000,000
2 Impervious Blanket	128,000	CY	5,833,000	1,458,000	7,291,000
3 Partial Cutoff Wall	620,400	SF	53,713,000	13,428,000	67,141,000
4 Abutment Cutoff Wall	60,200	SF	2,158,000	539,000	2,697,000
5 Downstream Seepage Blanket	186,000	CY	5,348,000	1,337,000	6,684,000
6 Rehab Relief Wells	1	JOB	633,000	158,000	791,000
7 Instrumentation	1	JOB	2,217,000	554,000	2,771,000
8 Mechanical/Electrical Upgrade	1	JOB	7,829,000	1,957,000	9,787,000
10 Environmental Protection	1	JOB	218,000	55,000	273,000
* Miscellaneous	1	EA	267,000	67,000	334,000
18 Culturual Resources	**1**	**JOB**	**700,000**	**175,000**	**875,000**
19 Buildings, Grounds, & Utilities	**1**	**JOB**	**304,000**	**76,000**	**380,000**
22 Feasibility Studies	**1**	**LS**	**1,782,000**	**0**	**1,782,000**
30 Engineering and Design	**1**	**LS**	**10,389,000**	**4,156,000**	**14,545,000**
31 Construction Management	**1**	**LS**	**6,001,000**	**1,500,000**	**7,502,000**

Table 12. Project cost estimate by major components at FY08 Price Level.

Refer to Appendix D. Baseline Cost Estimate and Appendix G. Fully Funded Cost and Schedule for additional information.

Several factors contributed to the increase of costs from the Screening Level Cost Estimate (Table 4) to development of the current Baseline Cost Estimate (Table 11). These factors were only applied to the recommended plan, and would not affect alternative selection. The following list describes the major areas where the cost increase occurred:

1. The Screening Level concrete cutoff wall was 592,000 SF at a cost of $50/SF without contingencies. A budgetary unit cost of the concrete cutoff wall was obtained from several contractors familiar with the work and costs ranged from $30-$50/SF (prior to contingencies). Since completion of that estimate, additional data has been gathered from multiple contracting sources and budgetary costs ranged from $45/SF to $80/SF without contingencies. In the Baseline, the size of the concrete cutoff wall increased to 620,400 SF and at a unit cost of $86.58/SF without contingencies was developed in detail using crews and material quotes. Costs for verification drilling have also been added to the Baseline to ensure the underseepage problems have been corrected. Total cost increase is $24.1 million without contingency.

2. The Abutment Cutoff Wall is now included as part of the major rehabilitation combined with radial grouting in the tunnels. In the Screening Level, these items were separate alternatives compared to a combination of the two in the Baseline.
3. The downstream seepage blanket was originally an IRRM measure but has now been included as part of major rehabilitation. The blanket has also been expanded to cover a larger area.
4. Costs have been added to include rehabilitation of the relief wells which was not in the Screening Level. Total cost increase is $633,000 without contingency.
5. Costs have been added to include additional instrumentation at the dam which was not in the Screening Level. Total cost increase is $2.22 million without contingency.
6. Costs have been added for mechanical and electrical upgrades which were not in the Screening Level. These upgrades consist of the purchase, removal, painting, and installation of six new gates along with rehabilitation of existing machinery. Total cost increase is $7.83 million without contingency.
7. Costs have been added to the 01 Account, Lands and Damages, and 22 Account, Feasibility Studies, to account for spent dollars which was not in the Screening Level. Total cost increase is $4,368 for the 01 Account and $1,782,424 for the 22 Account which included all costs spent on the project up to FY08.
8. Costs have been added to the 19 Account, Buildings, Grounds, & Utilities, for construction of a new project office which was not in the Screening Level. Total cost increase is $304,000 without contingency.
9. Costs have been added to the 18 Account, Cultural Resources, to account for any archaeological sites that may be encountered during construction. Total cost increase is $700,000 prior to contingency.
10. Costs have decreased for the 30 Account, Planning, Engineering and Design (E&D), from the Screening Level. E&D costs for the Screening Level were assumed to be 25% of construction costs. E&D for the Baseline was determined by collecting information from the PDT members. Currently, E&D in the Baseline is about 14.3% of construction costs which is below the historical percentage. This issue will be addressed further when performing the risk analysis.
11. Costs have increased in the 31 Account, Construction Management, for Supervision and Administration (S&A) costs during construction. The historical average of 7.5% of construction costs was used to determine S&A. Since the construction costs have increased since the Screening Level, so have the S&A costs due to the total increase in the project costs listed above. Total cost increase is about $2.81 million without contingency.

13.0 COST SHARING CONSIDERATIONS

Bolivar Dam was authorized for construction by the National Industrial Recovery Act, approved June 16, 1933. The Muskingum Watershed Conservancy District (MWCD) filed its original request to partner with the federal government through an application to the Federal Emergency Administration of Public Works in August 1933. The Administration allocated funds to the U.S. Army Corps of Engineers (USACE) to construct the projects. Construction of the Bolivar Dam was completed in September 1938 at a cost of $5,934,900 which included levees at Magnolia and East Sparta and associated study costs. In accordance with an agreement to partner in implementing the projects in the Muskingum River Basin, also known as "the 1934 Agreement", the Muskingum Watershed Conservancy District (MWCD) originally contributed $12,500,000 of the total cost of $34,590,000 for all dams in the Muskingum Basin (36 %). The Rivers and Harbors Act of 1938 (52 Stat. 1217) directed the Secretary of War to reimburse MWCD $4,500,000 reducing their cost share to $8,000,000 or 23 %. Under terms of the 1934 Agreement, USACE held complete responsibility for project construction. The MWCD held responsibility to acquire all necessary real estate, for which USACE later reimbursed it pursuant to the Rivers and Harbors Act of 1938. The MWCD later conveyed all real estate around the flood control pools and dam sites to the United States. Pursuant to § 4 of the Flood Control Act of 1939 (53 Stat. 1414), the MWCD transferred all operation and maintenance responsibility to the USACE.

The Bolivar Major Rehabilitation Project is being implemented in accordance with Engineer Pamphlet (EP) 1130-2-500, "Partners and Support (Work Management Guidance and Procedures)" dated 27 December 1996 and Engineer Pamphlet (EP) 1165-2-1 "Digest of Water Resources Policies and Authorities" dated 30 July 1999. In accordance with paragraph 3-3 of EP 1130-2-500 and paragraph 11-3 of EP 1165-2-1, Major Rehabilitation is comprised of one of two, or both, mutually exclusive categories – Reliability or Efficiency Improvement. Bolivar is categorized as a reliability improvement. There are no efficiency improvements. In accordance with paragraph B-3.1. of EP 1130-2-500, "Other cost sharing will be in accordance with any local (project) cooperation agreements related to the original project authorization.", the non-federal cost share is the original non-federal cost share for the Bolivar project, which was 23%. The Bolivar Dam is owned, operated and maintained by the U.S. Army Corps of Engineers.

14.0 REAL ESTATE REQUIREMENTS

MWCD has been identified as the cost-sharing non-Federal Local Sponsor for the project. There is no known sponsor owned land within the project area. Use of approximately 213 acres of Government owned land is needed to facilitate construction of the project. This excludes a 48.49 acre area that has cultural resource concerns. Stockpiling and spoil areas, downstream of the dam near the right abutment, will be needed to facilitate the construction and are included in this total. An access road, on Government property, will also be constructed. A borrow area will be utilized near the stockpiling/spoil areas to construct the access road. The Contractor's Work Limits (CWL) is located entirely within the Government boundary line; therefore, no private property will be required.

14.1 Facilities to be Relocated

A power distribution line, owned by the Ohio Power Company, will have to be relocated to accommodate project construction. According to the Preliminary Attorney's Opinion of Compensability completed on March 19, 2008, Ohio Power Company has no compensatory interest. The Government's interest remains superior to any interest obtained by Ohio Power Company and the facilities are subject to relocation without compensation.

A buried telephone cable, owned by Verizon North, Inc, will also have to be relocated to accommodate project construction. According to the Preliminary Attorney's Opinion of Compensability completed on March 19, 2008, Verizon North, Inc. has no compensatory interest. The Government's interest remains superior to any interest obtained by Verizon North, Inc. and the facilities are subject to relocation without compensation.

Refer to Appendix A, Real Estate Plan, for more detailed information on the real estate requirements for the project.

15.0 SUMMARY AND CONCLUSIONS

Based on a full consideration of the costs, benefits, environmental effects, public safety, and the technical considerations including the risks associated with each of the alternatives, implementation is recommended for the National Economic Development (NED) Plan, the combination of Main Embankment Partial Length/Depth Cutoff and Left Abutment Cutoff Wall. The Huntington District recommends that detailed design activities for the NED plan be implemented to insure the long term reliability of Bolivar Dam.

16.0 REFERENCES

USACE, 1996, Project Operations - Partners and Support (Work Management Guidance and Procedures), EP 1130-2-500.

USACE, 2007, Interim Risk Reduction Measures for Dam Safety, EC 1110-2-6064.

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